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Fort Collins, Colorado

COMPUTER SIMULATION OF SNOWMELT WITHIN A COLORADO SUBALPINE WATERSHED

by Charles F. Leaf and Glen E. Brink

Abstract

A dynamic model which simulates snowmelt in Colorado subalpine watersheds for all combinations of aspect, slope, elevation, and forest cover composition and density is described. The model simulates winter snow accumulation, the energy balance, snowpack condition, and resultant melt in time and space. Detailed flow chart descriptions of the various components of the model and a program listing are presented.

Keywords: Computer models, coniferous forests, model studies, simulation analysis, snowmelt, watershed management.

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COMPUTER SIMULATION OF SNOWMELT WITHIN A COLORADO SUBALPINE WATERSHED

by

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[1]*Central headquarters maintained at Fort Collins in cooperation with Colorado State University. Research reported here was conducted and partly financed in cooperation with the Division of Atmospheric Water Resources Management, Bureau of Reclamation, U.S. Department of the Interior.*

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Computer Simulation of Snowmelt Within a Colorado Subalpine Watershed

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The systems approach is a way to determine the probable effects of land management on the many interdependent hydrologic components in the Colorado subalpine forest. Accordingly, we are developing mathematical models to simulate the hydrology of this high-elevation ecosystem.

As a first step, we are modeling: (1) winter snow accumulation, (2) the energy balance, (3) snowpack condition, and (4) resultant melt in time and space under a variety of conditions. Combinations of aspect, slope, elevation, and forest cover composition and density are included. The computer program described was initially written by the Watershed Systems Development Unit at the Pacific Southwest Forest and Range Experiment Station (Willen et al. 1971). We have revised the original program to better represent conditions in the Rocky Mountain region. With this snowmelt model, we have simulated the probable effects of forest cover manipulation and additions to the winter snowpack through weather modification.

The model consists of three parts: (1) the determination of the form of precipitation (rain or snow), (2) the melting process, and (3) snowpack condition in terms of energy level and free water requirements. Shortwave and longwave radiation represent the energy available for snowmelt. In the forested environment, shortwave radiation reaching the pack is estimated by means of a transmissivity coefficient function, which depends on the density and composition of the forest cover (Miller 1959, Reifsnyder and Lull 1965). Radiation inputs are adjusted for slope and aspect (Frank and Lee 1966). Reflectivity of the snowpack is varied according to precipitation, the energy balance, and time (U.S. Army 1956).

The snowpack is assumed to behave as a dynamic heat reservoir; thus all elements in the snowmelt portion of the model are expressed in units of heat. The net external energy balance is computed at the snow surface. Rain and snow are converted from inches at the prevailing air temperature to equivalent gram-calories. Each precipitation event is added algebraically as a caloric-heat event to develop the heat reservoir or snowpack. Temperatures within the snowpack are computed using unsteady heat flow theory. The snowpack will yield melt water only when it has reached a zero energy deficit (snowpack temperature = 0° C) and its free water holding capacity is satisfied. Snowmelt rates after the pack is primed are governed primarily by the longwave and shortwave energy balances at the snow surface. The discussion which follows is a detailed flow chart description of the various components of the model. The model has been programed for the CDC 6400 computer[2] at Colorado State University.

Program Description

Program MELTMOD (Main Program)

The main program (fig. 1) makes no computations, but serves only to coordinate the flow of the program. Within the listing of the main program is included a dictionary of all variables that are available for use and cross referencing by the subroutines as well as the main program. (This allocation of computer memory for mutual access by many routines is designated "blank common.") Other dictionaries appear throughout the subroutines for variables used exclusively within those routines. Blank common is arranged so that additional variables may be added easily; by using a very extensive blank common, the routines were broken down into simpler logical units rather than one or two

[2]*The use of trade and company names is for the benefit of the reader; such use does not constitute an official endorsement or approval of any service or product by the U. S. Department of Agriculture to the exclusion of others that may be suitable.*

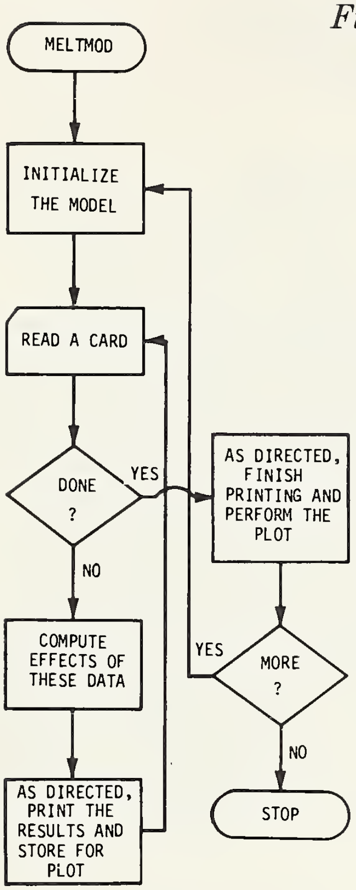

Figure 1.

large routines. The model contains 10 subroutines, discussed in the following order:

1. AFFECTS	6. LINK
2. CALIN	7. MIXTURE
3. CALOSS	8. RADBAL
4. DIFMOD	9. RAINED
5. GETREF	10. SNOWED

The parameters which describe the initial conditions in the model are solar radiation transmissivity coefficient, forest cover density, an initial pack temperature and water equivalent, and a threshold value for use in the reflectivity subroutine, GETREF. The data items supplied on a daily basis for the simulation are incoming shortwave radiation, daily maximum and minimum temperatures, observed water equivalent (optional), precipitation, and density of the snowpack (optional). Observed snowpack temperatures for use by the diffusion model, subroutine DIFMOD, are also optional, but recommended.

1. Subroutine AFFECTS (fig. 2)

The decisions necessary to compute the response to input data are started within this routine and continued in other routines. The primary decision to be made here is the classification of a precipitation event. An event is classified as follows:

a. If the daily minimum temperature is less than or equal to 32° F, **or** if the daily maximum temperature is less than or equal to 35° F, it is a snow event.
b. If the minimum temperature is greater than 35° F, it is a rain event.
c. If the minimum temperature is between 32° F and 35° F, **and** the maximum temperature is greater than 35° F, it is a mixture of rain and snow event. The total precipitation is partitioned into rain and snow by the formula presented in subroutine MIXTURE.

The precipitation is added to the snowpack, and the caloric input or loss due to the precipitation is calculated. Effects on the snowpack are computed by subroutines

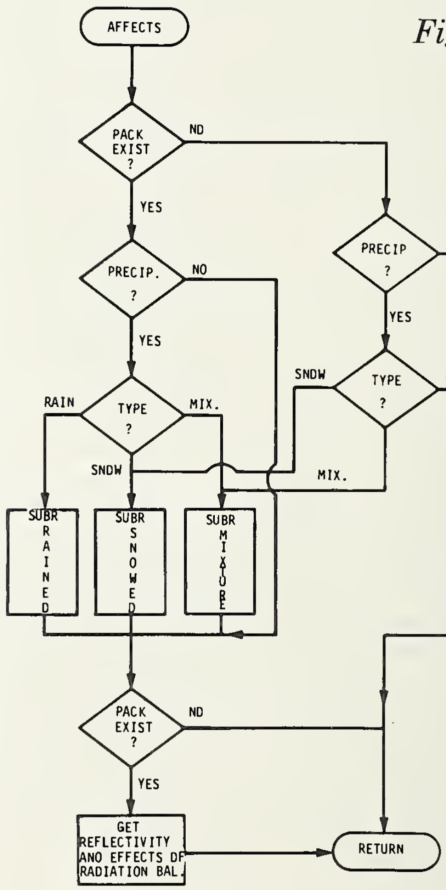

Figure 2.

CALIN or CALOSS. Subroutines GETREF and RADBAL are then called to compute the reflectivity of the pack, and the influences of the radiation balance as computed from air temperature.

2. Subroutine CALIN (fig. 3)

This routine computes the effects of caloric input from either the radiation balance or from rainfall. A check is made to see if the input satisfies an exisiting calorie deficit, given by the equation

$$CALDEF = 203.2\ W_c \qquad [1]$$

where

CALDEF = heat deficit of the snowpack in calories, and

W_c = the "cold content" which represents the heat required to raise the snowpack to 0° C, in equivalent inches of water (U.S. Army 1960).

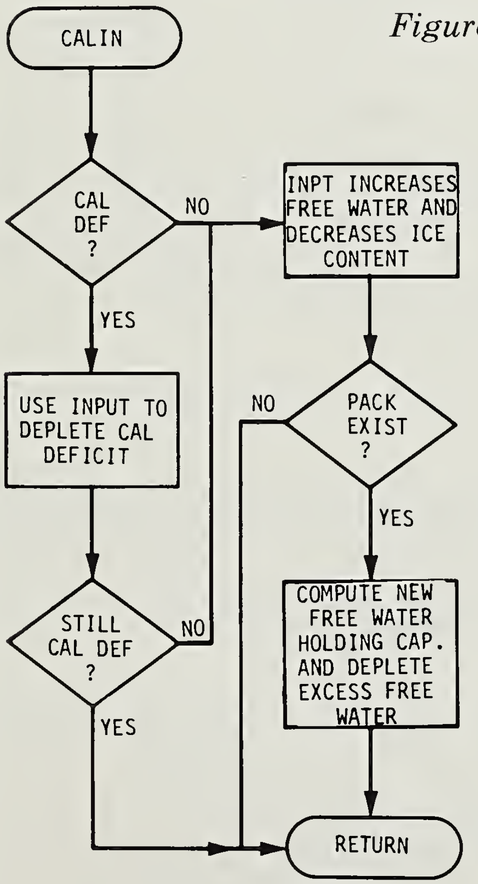

Figure 3.

If the input energy is not sufficient to make up the heat deficit, the only action taken is to adjust the pack temperature to compensate for the input. If the calorie deficit is satisfied and there is still sufficient input to generate melt, the melt is added to the free water content of the snowpack and deleted from the ice content. A new free water holding capacity is then computed (4 percent by weight of the ice content) and any excess free water is deleted from the pack.

3. Subroutine CALOSS (fig. 4)

This routine computes the effects of a loss of energy from the pack. The loss may be due to either a negative radiation balance (the back radiation exceeding incoming radiation) or "cold content" added by precipitation (fresh snow). The snowpack is first examined to see if any free water is present in the pack; if not, the calorie deficit is increased to compensate for the loss. If free water is present, the loss is used to freeze all or part of it (80 calories per cm. of free water). If the loss is more than sufficient to freeze all of the free water the remaining heat loss is used to create a calorie deficit (eq. 1).

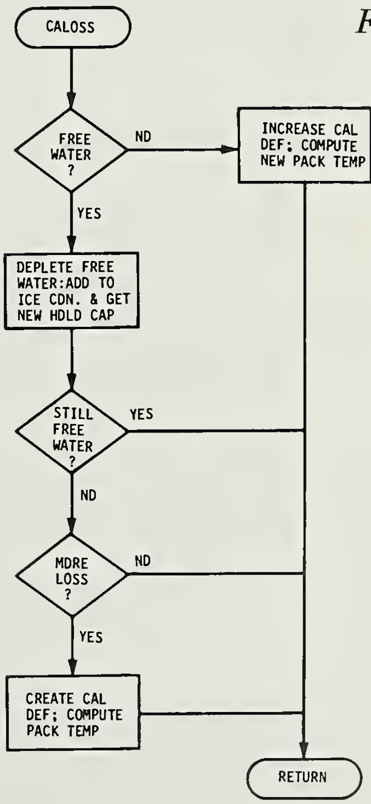

Figure 4.

4. Subroutine DIFMOD (fig. 5)

This routine controls the snowpack temperature through the winter months. Because the snowpack is typically below 0° C during much of the snow accumulation season, heat flow theory is used to index its thermal regime.

Total heat energy input to the snowpack is represented by air temperature measured 3 to 4 feet above the snow surface. The temperature in this boundary layer region is assumed to be an integration of all the processes involved, including incoming and outgoing radiation, wind, temperature, and humidity in the overlying airmass. The heat flow equation as solved by this routine is given by Quick (1967) and Riley et al. (1969):

$$k_s \frac{\partial^2 T_s}{\partial z^2} = c_s \rho_s \frac{\partial T_s}{\partial t} \qquad [2]$$

where

k_s = thermal conductivity in cal/°C/cm/sec,
c_s = specific heat in cal/gm/°C,
ρ_s = snowpack density in gm/cm³
T_s = snowpack temperature in °C ,
z = depth within snowpack (from surface) in cm., and
t = time in sec.

Equation [2] can be rewritten as:

$$\frac{\partial^2 T_s}{\partial z^2} = K_v \frac{\partial T_s}{\partial t} \qquad [3]$$

where

K_v = thermal diffusivity in cm²/sec.

The thermal diffusivity is assumed to vary with density according to the relation proposed by Schwerdtfeger (1963):

$$K_v = \frac{2\, k_i}{(3\rho_i - \rho_s)c_i} \qquad [4]$$

where

k_i = thermal conductivity of ice in cal/°C/cm/sec.,
ρ_i = density of ice in gm/cm³, and
c_i = specific heat of ice in cal/gm/°C.

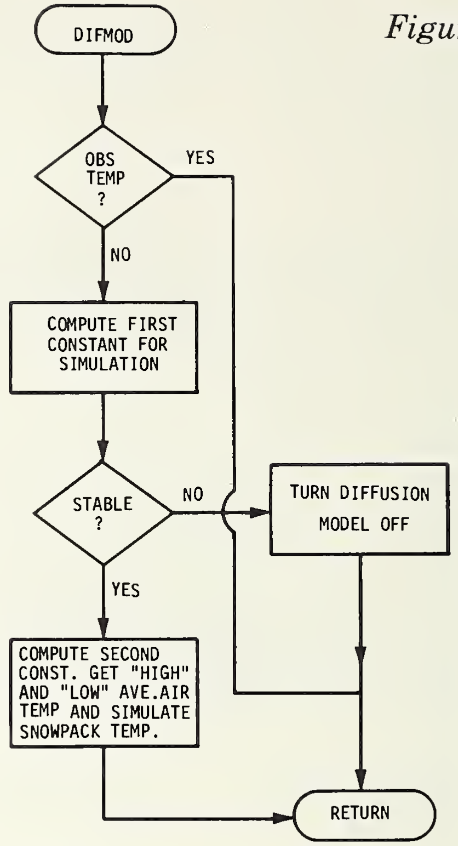

Figure 5.

The density is assumed to be constant throughout the pack, although it may vary with time.

A finite difference solution for equation [3] is obtained as follows (Smith 1965, Richtmyer and Morton 1967):

Let

$$\frac{\partial u}{\partial t} = \sigma \frac{\partial^2 u}{\partial x^2} \qquad \sigma = \text{const.} > 0 \qquad [5]$$

where equation [5] is the nondimensional form of equation [3]. (It should be noted that the number representing the depth of the pack is 1.)

The forward difference approximation to equation [5] is given by

$$\frac{u_{i,j+1} - u_{i,j}}{m} = \frac{u_{i+1,j} - 2u_{i,j} + u_{i-1,j}}{h^2} \qquad [6]$$

where

$x = ih, (i = 0, 1, 2, \ldots)$
$t = jm \; (j = 0, 1, 2, \ldots)$

Equation [6] can be written as:

$$u_{i,j+1} = u_{i,j} + \frac{mK_v}{h^2}(u_{i-1,j} - 2u_{i,j} + u_{i+1,j}) \quad [7]$$

which gives the explicit solution for the unknown temperature $u_{i,j+1}$ at the (i,j+1) th mesh point in terms of known temperatures along the j th time row. Hence, it becomes possible to calculate the unknown pivotal values of u along the first time row, t = m(fig. 6) in terms of known boundary and initial values along t = 0, then the unknown pivotal values along the second time row in terms of the calculated pivotal values along the first, and so forth.

Equation [7] utilizes the average air temperature (assumed to be the temperature of the surface of the snowpack), ground temperature, and temperature at the midpoint of the snowpack during the previous interval to simulate present snowpack temperature. The midpoint temperature is defined initially from observed data and simulated thereafter. The diffusion model has been found to be mathematically stable only for reasonably deep packs (≥4.7 inches of water equivalent). To insure stability in the model, each 24-hour period is divided into two 12-hour intervals and the result is averaged. The average air temperatures for each 12-hour interval are the "high average" (the mean of the maximum and daily mean temperatures) and the "low average" (the mean of the minimum and daily mean temperatures.)

Once the snowpack becomes isothermal, subroutine RADBAL computes the energy balance. Subroutine LINK determines when the diffusion model is to be used and when the radiation balance is to be used. The diffusion model may be initialized or readied by external controls or when the radiation balance creates a calorie deficit.

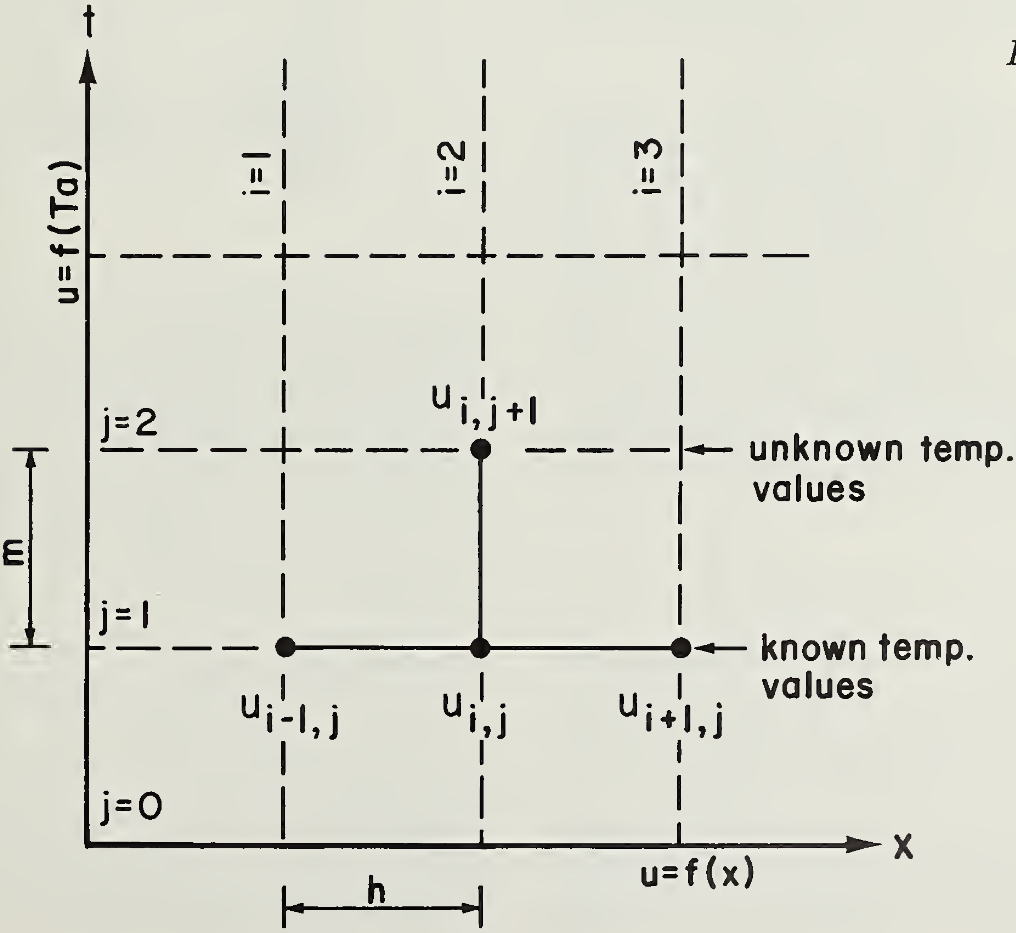

Figure 6.

5. Subroutine GETREF (fig. 7)

This routine selects the reflectivity for use in the radiation balance routine, RADBAL. In essence, there are two functions from which the reflectivity is selected: one for the accumulation phase of the snowpack and one for the melt phase (U.S. Army 1960). The reflectivity is assumed to start at a higher value and to decrease more slowly with time during accumulation than during the melt season. To determine which function to use, a check is made on the following conditions:

a. If no new snow was added to the pack during a given day, the length of time since fresh snow is increased by 1 day and the function used on the previous day is used again. The accumulation function computes reflectivity for 15 consecutive days. After 15 days, control shifts to the next lower value in the melt function, which computes reflectivity for an additional 26 days. After this period of time, the reflectivity is a constant 40 percent. The minimum value for the reflectivity in any case is assumed to be 40 percent.

b. If new snow has fallen on the pack, a further check is made to see if it was a "spring" or "winter" snow. This is determined by comparing the maximum daily temperature against a temperature threshold which varies according to elevation, forest cover, and aspect. If it is warmer than the threshold, no change is made and the control flows as explained in part a. If it is colder, indicating "winter" snow conditions, another check determines if the snowpack is isothermal and thus selects which function to use while re-initializing the day counter.

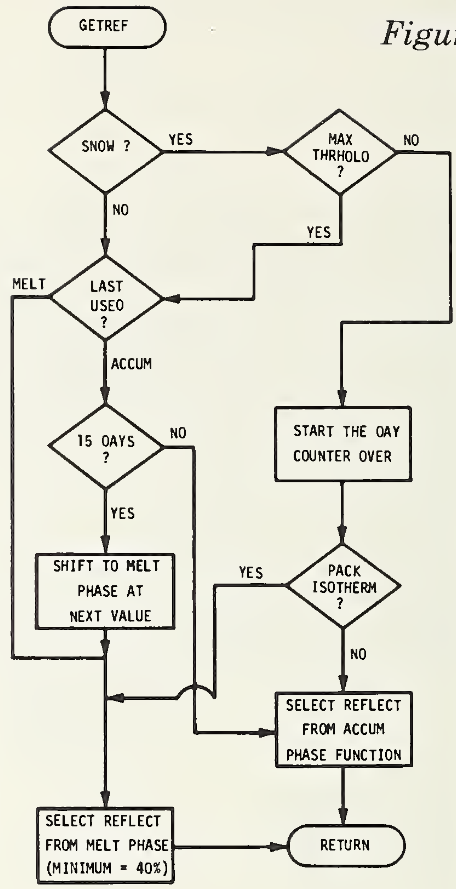

Figure 7.

6. Subroutine LINK (fig. 8)

This routine is the interface between the thermal diffusivity model and the radiation balance routine. As discussed above, the diffusion model is used to control the snowpack temperature during the winter season. Air temperature is the driving variable in both routines, so they are somewhat related. The decision as to which method to use is basically dependent on whether the snowpack is still under "winter" conditions or "spring" conditions. The first check is to see if the radiation balance has simulated a caloric gain or loss from the pack. A loss requires a check to see if the pack has been isothermal with free water content ("spring") or if it has been cold ("winter"). If it was already cold, the diffusion model is used without further question. If the pack did contain free water, the loss is used to freeze it and, if a calorie deficit would be created, the diffusion model is re-initialized to isothermal conditions and the radiation balance is adjusted accordingly. In the event of a caloric gain, a check is made to see if the calorie deficit would be satisfied; if not, the diffusion model is used. If the deficit is satisfied, a further check is made to see if at least 0.05 inch of free water is generated; if not, the diffusion model is set to isothermal conditions and control passes to the diffusion model. However, if sufficient free water is generated, the diffusion model is turned off and the radiation balance resumes full control.

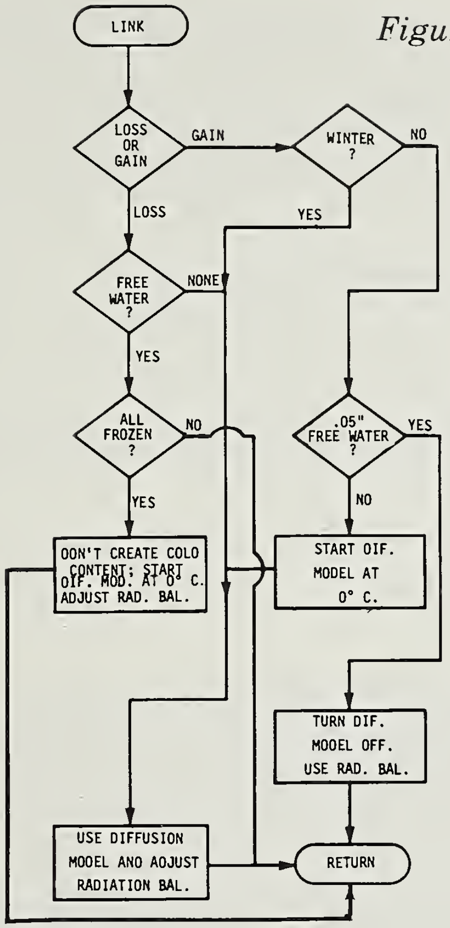

Figure 8.

passes to the subroutines that make the computations for a snow event and a rain event.

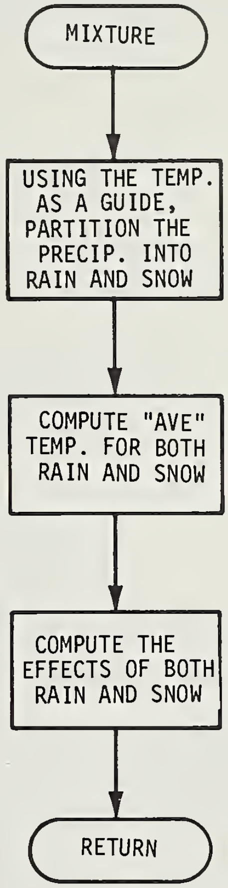

Figure 9.

7. Subroutine MIXTURE (fig. 9)

This routine partitions rain and snow precipitation components which fall on days when the maximum temperature is greater than 35° F and the minimum temperature is greater than 32° F, but less than 35° F. The partitioning is performed through the following equation:

$$\text{SNOW} = (\text{PRECIP})\ (1 - \text{B/A}) \qquad [8]$$

where

B = the difference between the maximum temperature and 35°,

A = the difference between the maximum and minimum temperatures.

The "average" temperature for the snow period is computed as the mean of the minimum temperature and 35°, while that for rain is the mean for the maximum and 35°. Control then passes to the subroutines that make the computations for a snow event and a rain event.

8. Subroutine RADBAL (fig. 10)

This routine uses air temperature to compute the net radiation balance through the Stefan-Boltzmann function as follows:

$$L_P = \sigma T^4 \qquad [9]$$

where

L_P = potential longwave radiation at a given temperature,

σ = Stefan-Boltzmann constant for a 24-hour period: 1.17×10^{-7} (langleys)/(day)/(°K)$^{-4}$, and

T = temperature in °K.

The shortwave radiation component in the radiation balance is computed as a simple function of the transmissivity coefficient and

the cover density. Solar radiation is adjusted for slope and aspect, according to tables published by Frank and Lee (1966). The downward longwave component is computed by using the average air temperature in the Stefan-Boltzmann function according to the equations:

From sky to snow:

$$L_S = \alpha(1 - C_D)(1.17 \times 10^{-7})(T_A{}^4) \qquad [10]$$

where

C_D = forest cover density expressed as a decimal,
T_A = ambient air temperature in °K, and
α = a factor (1 or 0.75) which accounts for clear or cloudy skies.

From forest cover to snow:

$$L_F = 1.17 \times 10^{-7} C_D T_F{}^4 \qquad [11]$$

where
T_F = radiation temperature of foliage in °K.

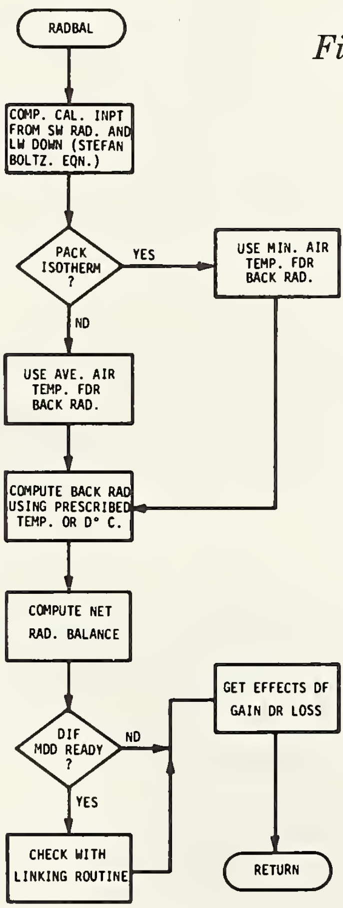

Figure 10.

The upward component (back radiation) is computed by using either the average daily air temperature ("winter" conditions) or the minimum air temperature ("spring" conditions) for the radiation temperature of the snowpack. In the case of the back radiation, however, the temperature used must be less than or equal to 0° C. The equations used are:

From snowpack to forest:

$$L_{SF} = 1.17 \times 10^{-7} C_D T_S{}^4 \qquad [12]$$

where

T_S = radiation temperature of the snowpack in °K.

From snowpack to sky:

$$L_{SS} = (1 - C_D)(1.17 \times 10^{-7})(T_S{}^4) \qquad [13]$$

Once the upward and downward components have been calculated, they are combined to get a net longwave balance as follows: if the skies are clear (no precipitation), only 75 percent of the downward longwave radiation given by equation [10] is combined with the back radiation from the snowpack (U.S. Army 1960). The radiation balance under the forest canopy is computed by equations [11] and [12]. During "winter" conditions, $T_F = T_S$ and $L_F = L_{SF}$. If there was precipitation, a check is made to see if it was snow. When there is snow, the longwave balance is assumed to be zero. Otherwise, under cloudy skies, the downward component and the back radiation are merely combined algebraically.

Once the net radiation is computed, the decision is made by the linking routine to use either the diffusion model or the radiation balance. The effects of the decision are then computed by either Subroutine CALIN or Subroutine CALOSS, depending upon the net gain or loss registered by the radiation balance.

9. Subroutine RAINED (fig. 11)

This routine computes the effects of a rain event on the snowpack according to the equation:

$$L_W = (C_R)(\Delta T)(P_R) \qquad [14]$$

L_W = calorie gain due to rainfall

C_R = specific heat of water: 1 cal./gm/° C ,

ΔT = difference between temperature (°C) at which rain falls and 0° C , and

P_R = amount of rainfall in centimeters.

If the pack is cold, the caloric input from the rain is used to satisfy all or part of the calorie deficit. If the input more than satisfies the deficit, the remainder is contributed as free water and the caloric input from that remaining is allowed to generate other melt. If the pack was already isothermal, the entire amount of rain is added to the pack as free water, and the calories contribute to the melt rate.

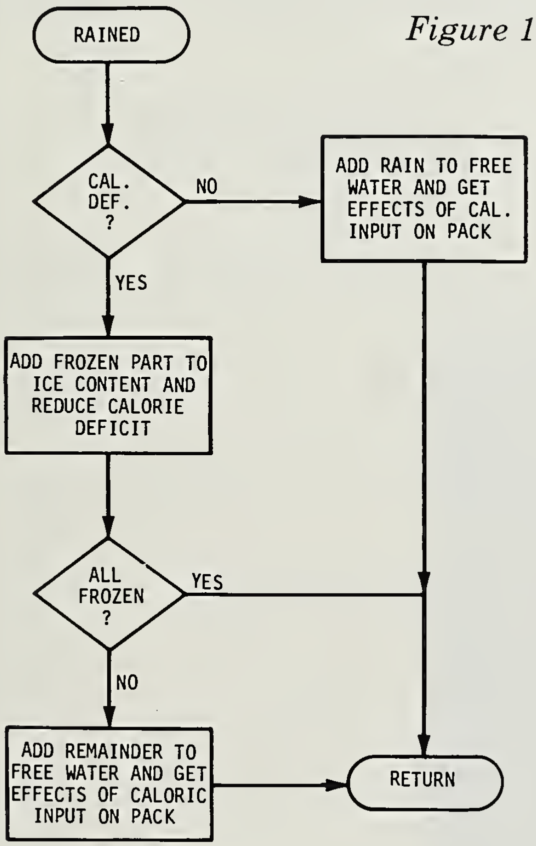

Figure 11.

10. Subroutine SNOWED (fig. 12)

This routine computes the effects of a snow event on the snowpack according to the equation

$$L_I = (C_S)(\Delta T)(P_S) \qquad [15]$$

where

L_I = calorie gain or loss due to snowfall,

C_S = specific heat of ice: 0.5 cal./gm/° C ,

ΔT = difference between temperature (° C) at which snow falls and 0° C , and

P_S = water equivalent of snowfall in centimeters.

If the snow falls within the "warm" range of 32° to 35° F, no action is taken concerning the caloric loss. However, snow falling at lower temperatures increases the calorie deficit, and this change is accounted for.

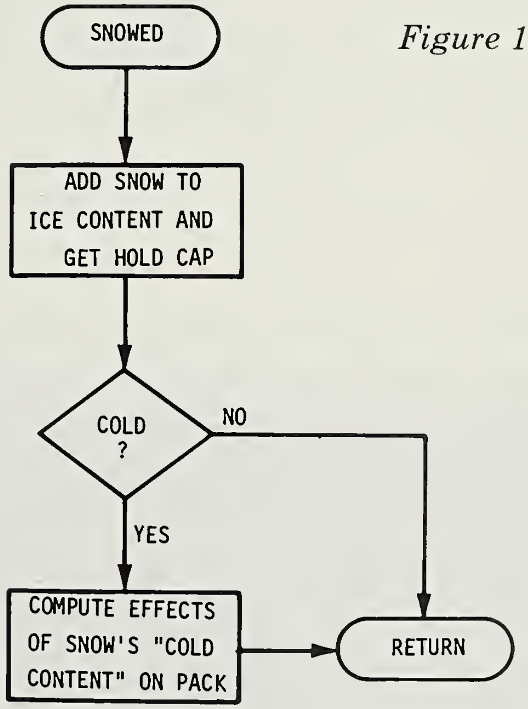

Figure 12.

Unlisted Routines

The routines listed below are not included in the flow-charted descriptions since they are merely utility routines for handling input, output, or internal processing of the information. They are not part of the model; rather, they are the necessary routines to implement the model on a digital computer.

INITIAL	RDPACK	STORE
PLOTTER	READER	WRITER

A complete listing of the snowmelt model as described above is included in appendix I.

Model Verification

The model has been tested on field data obtained from the 667-acre Deadhorse Creek watershed (fig. 13) at the Fraser Experimental Forest (Leaf 1971). Snowmelt rates at eight locations on Deadhorse Creek were reconstituted (fig. 14). Agreement between observed and simulated melt rates was good at all locations. The model is structured so that a minimum number of variables must be adjusted to obtain a satisfactory fit. In this case, only two variables were adjusted to obtain satisfactory agreement: (1) cover density (a vegetation type and composition parameter), and (2) a shortwave radiation transmissivity coefficient. Figure 15 compares observed and simulated snowpack accumulation and melt at the high-elevation north slope and low-elevation south slope sites on Deadhorse Creek in 1969. Table 1 is an example of the computer output.

With the cover density and transmissivity coefficients fixed as determined in 1969, the model has given good results in simulating snowmelt on Deadhorse Creek for the 1964-71 runoff seasons. Although it is a simplification of the real life system, the model produces reliable results.

Empirical studies have shown that various watershed management practices exert a significant effect on snowmelt rates and resultant streamflow. Because the model described here is a mechanistic representation of the snowmelt process, its careful use should enable the resource manager to better understand how a given management alternative will affect snowmelt **before** it is implemented. We believe it to be a useful tool for predicting the probable effects of land management practices on the timing and amount of snowmelt.

Figure 13. — Aerial view (foreground) of Deadhorse Creek watershed, Fraser Experiment Forest. The north-facing slope is in the lower lefthand corner of the photograph.

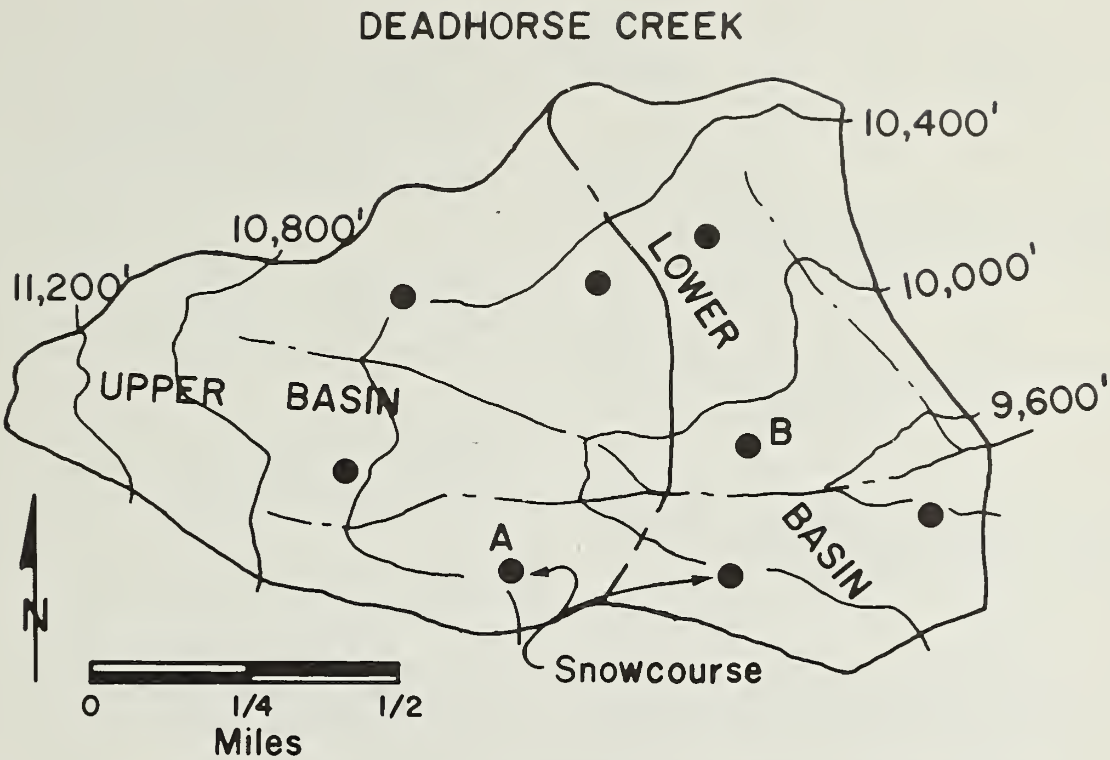

Figure 14. — Locations where field measurements were taken on Deadhorse Creek.

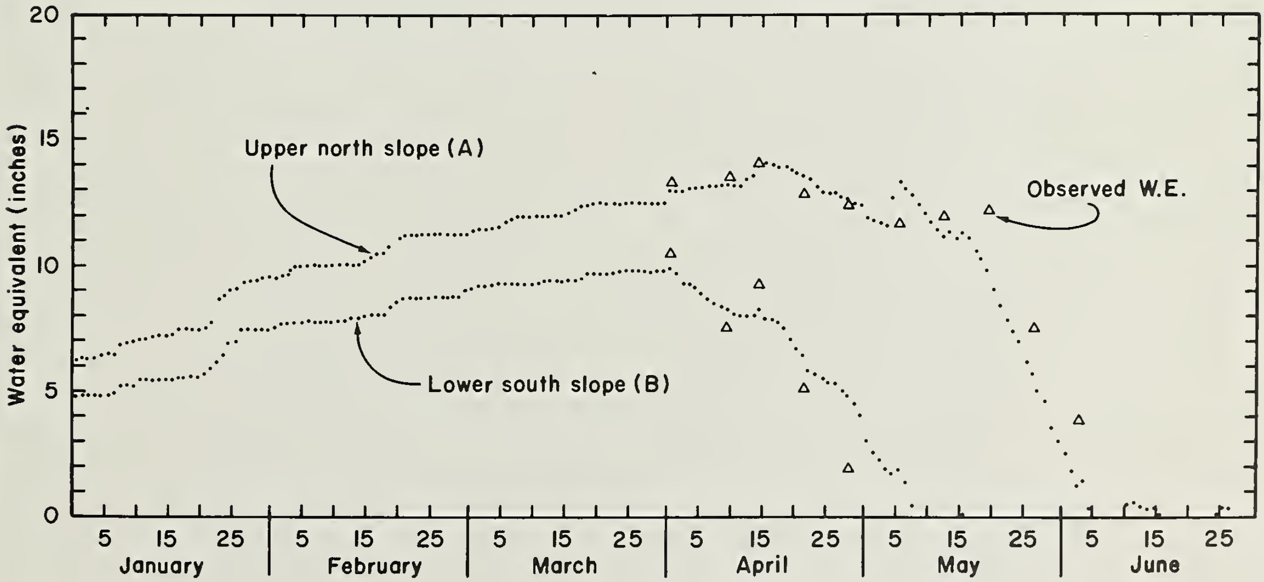

Figure 15. — Observed and simulated snowmelt on upper north (A) and lower south (B) slopes during 1969 snowmelt runoff season.

TABLE 1

SNOWMELT RUNOFF SIMULATION MOOEL
FRASER EXPERIMENTAL FOREST, COLORAOO
OEAOHORSE CREEK, UPPER NORTH SLOPE

TRANSMISSIVITY COEFFICIENT = .25 COVEP OENSITY = .55

OATE	TEMPERATURE (F) MAX	MIN	AVE	PRECIP (IN) OAY	ACCUM	NET RAO (CAL) SHORT	LONG	ENERGY BAL (CAL)	SNOWPACK TEMP (C)	PREOICTEO W.E. (IN)
4 7 69	30.0	12.0	21.0	0.11	13.45	8.3	-7.3	0.1	-1.0	13.45
4 8 69	32.0	13.0	22.5	0.00	13.45	13.5	-18.0	-4.5	-1.3	13.45
4 9 69	36.0	18.0	27.0	0.00	13.45	29.4	-49.5	-20.1	-2.4	13.45
4 10 69	40.0	23.0	31.5	0.00	13.45	30.7	-21.3	9.5	-1.9	13.45
4 11 69	45.0	27.0	36.0	0.00	13.45	25.7	-20.6	5.1	-1.6	13.45
4 12 69	34.0	25.0	29.5	.29	13.74	8.9	-5.6	2.8	-1.4	13.74
4 13 69	33.0	23.0	28.0	0.00	13.74	28.4	-22.4	6.1	-1.0	13.74
4 14 69	36.0	22.0	29.0	0.00	13.74	31.4	-30.8	.6	-1.0	13.74
4 15 69	40.0	20.0	30.0	.76	14.50	24.2	-30.8	-7.7	-1.4	14.50
4 16 69	28.0	15.0	21.5	.11	14.61	3.1	-.7	1.5	-1.3	14.61
4 17 69	32.0	15.0	23.5	0.00	14.61	22.9	-22.4	.6	-1.3	14.61
4 18 69	40.0	16.0	28.0	0.00	14.61	23.7	-24.7	-1.0	-1.3	14.61
4 19 69	44.0	22.0	33.0	0.00	14.61	34.3	-32.0	2.3	-1.2	14.61
4 20 69	47.0	17.0	32.0	0.00	14.61	38.6	-36.6	2.0	-1.1	14.61
4 21 69	53.0	30.0	41.5	0.00	14.61	40.3	-38.0	2.4	-1.0	14.61
4 22 69	45.0	33.0	39.0	0.00	14.61	34.1	-22.5	11.6	-.3	14.61
4 23 69	55.0	32.0	43.5	.52	15.13	37.4	-31.1	6.2	0.0	15.13
4 24 69	52.0	24.0	38.0	0.00	15.13	45.7	-1.0	44.7	0.0	15.13
4 25 69	24.0	9.0	16.5	0.00	15.13	36.5	-27.4	9.1	0.0	15.13
4 26 69	20.0	8.0	14.0	.14	15.27	16.9	0.0	15.1	0.0	15.27
4 27 69	27.0	8.0	17.5	0.00	15.27	33.0	-18.5	14.5	0.0	15.27
4 28 69	38.0	15.0	26.5	0.00	15.27	45.0	-11.2	33.7	0.0	15.27
4 29 69	42.0	22.0	32.0	0.00	15.27	48.3	-19.8	28.5	0.0	15.13
4 30 69	47.0	26.0	36.5	0.00	15.27	56.6	-18.5	38.1	0.0	14.94

ELEVATION 10500 FT.
ASPECT NE, SLOPE 35 PERCENT

Literature Cited

Frank, Ernest C., and Richard Lee.
1966. Potential solar beam irradiation on slopes. Tables for 30° to 50° latitude. U.S. For. Serv. Res. Pap. RM-18, 116 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Leaf, Charles F.
1971. Areal snow cover and disposition of snowmelt runoff in central Colorado. USDA For. Serv. Res. Pap. RM-66, 19 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Miller, D.H.
1959. Tranmission of insolation through pine forest canopy as it affects the melting of snow. Schweiz. Anst. f. Forst. Versuchsw. Mitt. 35: 57-79.

Quick, M. C.
1967. A comparison of measured and theoretical snowpack temperatures. J. Hydrol. 5: 1-20.

Reifsnyder, William E.
1965. Radiant energy in relation to forests. U.S. Dep. Agric. Tech. Bull. 1344, 111 p.

Richtmyer, R. D., and K. W. Morton.
1967. Difference methods for initial-value problems. Ed. 2, 405 p. N.Y.:Intersci. Pub., John Wiley and Sons.

Riley, J. P., D. C. Chadwick, and K. D. Eggleston.
1969. Snowmelt simulation. West Snow Conf. [Salt Lake City, Utah] Proc. 37: 49-56.

Schwerdtfeger, P.
1963. Theoretical derivation of the thermal conductivity and diffusivity of snow. U.G.G.I. Int. Assoc. Sci. Hydrol. Comm. Pub. 61, p. 75-81.

Smith, G. D.
1965. Numerical solution of partial differential equations. 179 p. N.Y.: Oxford Univ. Press.

United States Army.
1956. Snow hydrology. Summary report of the snow investigations. Corps of Eng., N. Pac. Div., 437 p. Portland, Oreg.

____
1960. Runoff from snowmelt. Corps of Eng. EM 1110-2-1406, 59 p.

Willen, D. W., C. A. Shumway, and J. E. Reid.
1971. Simulation of daily snow water equivalent and melt. West. Snow Conf. [Billings, Mont.] Proc. 39: 1-8.

Appendix I: Complete Listing of Snowmelt Model

Program MELTMOD

```
      PROGRAM MELTMOD (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
C-----THIS IS A REWRITTEN VERSION OF -SNMELT-, A SNOW ACCUMULATION MODEL
C----- DEVELOPED BY THE U. S. FOREST SERVICE AT BERKELEY.  THE RADIATION
C----- BALANCE, AS DERIVED FROM AIR TEMPERATURE, SERVES AS THE MODEL
C----- PARAMETERS AND CHARACTERISTICS.
C-----
C-----DICTIONARY OF BLANK COMMON
C-----
C     ACTDATE - THE DATE OF THE RECORDING OF THE VALUES IN -ACTUAL-
C     ACTUAL - THE OBSERVED SNOWPACK TEMPERATURES USED TO INITIALIZE THE
C              DIFFUSION MODEL (SUBROUTINE DIFMOD).  LOCATIONS 1
C              THROUGH 19 ARE THE OBSERVED TEMPERATURES AND LOCATION
C              20 IS THE GROUND TEMPERATURE (-XX.X DEGREES C).
C              LOCATION 21 IS THE DISTANCE BETWEEN THE MEASURED
C              SNOWPACK TEMPERATURES (XX.X INCHES - USUALLY 6 IN.)
C     AVETEMC - THE DEGREES CENTIGRADE EQUIVALENT OF -AVETEMF-
C     AVETEMF - MEAN OR AVERAGE OF THE MAXIMUM AND MINIMUM TEMPERATURE
C              IN DEGREES FARENHEIT
C     BASTEMF - BASE TEMPERATURE DEGREES FARENHEIT, RAIN TURNS TO SNOW
C     CALAIR - POTENTIAL LONGWAVE CALORIC INPUT AT AIR TEMPERATURE
C     CALDEF - THE CALORIE DEFICIT IS THE NUMBER OF CALORIES NEEDED
C              TO BRING THE SNOWPACK TEMPERATURE TO ZERO DEGREES
C              CENTIGRADE (NOTE SHOULD BE MADE THAT IT IS A POSITIVE
C              QUANTITY)
C     CALORIE - CALORIES OF HEAT ABSORBED OR RELEASED BY THE SNOWPACK
C              FROM THE NET RADIATION BALANCE
C     CALSNOW - POTENTIAL LONGWAVE CALORIC LOSS AT SNOW TEMPERATURE
C     CDVDEN - THE COVER DENSITY IS THE FRACTION OF THE GROUND OR SNOW
C              SURFACE SHADED FROM DIRECT SUNLIGHT OR RADIATION
C     DATE - THE DATE BEING PROCESSED IN MMDDYY FORMAT
C     DATES - AN ARRAY OF THE DATE BEING PROCESSED.  THE FIRST WORD IS
C              THE MONTH, THE SECOND THE DAY, AND THE THIRD THE YEAR
C     DEN - THE SNOWPACK DENSITY READ FROM INPUT CARDS
C     DENSITY - THE DENSITY OF THE SNOWPACK USED IN THE DIFFUSION MODEL.
C              IF -DEN- IS ZERO OR BLANK, -DENSITY- IS COMPUTED AS A
C              FUNCTION OF THE PREDICTED WATER EQUIVALENT
C     DREADY = 0, DIFFUSION MODEL (SUBROUTINE DIFMOD) NOT INITIALIZED
C            = 1, DIFFUSION MODEL INITIALIZED AND READY FOR SNOWPACK
C              TEMPERATURE SIMULATION
C     ENGBAL - THE TOTAL CALORIC INPUT TO OR LOSS FROM THE SNOWPACK
C              DURING AN INTERVAL.  IT IS THE ALGEBRAIC SUM OF THE
C              ENERGY INVOLVED WITH THE PRECIPITATION AND THAT OF
C              THE RADIATION BALANCE, - CALORIE-
C     FOOTNOT - ARRAY OF FOOTNOTES TO BE PRINTED AT THE BOTTOM OF EACH
C              PAGE.  TWO CARDS ARE READ, THE FIRST 130 CHARACTERS
C              FORMING ONE LINE AND THE LAST 30 CHARACTERS FORMING A
C              SECOND LINE
C     FREEWAT - THE FREE WATER BEING HELD BY THE SNOWPACK
C     HOLOCAP - THE FREE WATER HOLDING CAPACITY OF THE SNOWPACK
C              (ASSUMED TO BE FOUR PERCENT OF THE WATER EQUIVLAENT)
C     IDATE - ARRAY FOR STORING THE DATES FOR PLOTTING
C     ISNOW - A SWITCH TURNED ON BY SUBROUTINE SNOWED WHEN THE PRECIP
C              WAS SNOW AND THEN OFF BY SUBROUTINE GETREF AFTER
C              COMPUTING THE REFLECTIVITY FOR THE GIVEN INTERVAL
C     ITABLE = 0, NO PRINTING OF TABULATED RESULTS FROM THE SIMULATION
C            = 1, PRINT THE TABULATED RESULTS FROM THE SIMULATION
C     KOUNT - COUNTER FOR THE NUMBER OF CARDS READ, MAXIMUM OF 372 DUE
C              TO THE DIMENSIONS OF THE VARIABLES FOR STORING THE
C              INFORMATION FOR PLOTTING
C     LASTUSD - AN INDICATOR USED IN SUBROUTINE GETREF TO DETERMINE
C              WHICH REFLECTIVITY FUNCTION TO USE
C     LINES - THE LINE COUNTER FOR PAGE EJECTION
C     NEXTACT - A ONE COLUMN CODE (COL 70) ON THE INPUT CARDS TO
C              INDICATE WHEN A CARD CONTAINING THE ACTUAL SNOWPACK
C              TEMPERATURES IS TO BE READ.  WHEN COLUMN 70 IS NOT
C              BLANK OR ZERO, CONTROL SHIFTS TO SUBROUTINE RDPACK
C              WHICH THEN READS THE NEXT CARD
C     OBSWEQV - OBSERVED WATER EQUIVALENT OF THE SNOWPACK IN INCHES
C     PACKTEM - THE EFFECTIVE TEMPERATURE OF THE SNOWPACK
C     PARTICE - THE PORTION OF THE PREDICTED WATER EQUIVALENT THAT IS
C              ICE.  THIS QUANTITY PLUS FREE WATER IS THE TOTAL
C              PREDICTED WATER EQUIVALENT (-PREWEQV-)
C     PASTINT - NUMBER OF INTERVALS SINCE THE LAST INITIALIZATION OF THE
C              REFLECTIVITY FUNCTION
C     PLOTOBS = 0, DO NOT PLOT THE OBSERVED WATER EQUIVALENT
C              1, PLOT THE OBSERVED WATER EQUIVALENT (OPERATIVE ONLY IF
C              -PLOTWE- IS TURNED ON)
C     PLOTWE = 0, DO NOT PLOT THE SIMULATION
C            = 1, PLOT THE SIMULATION, PRECIP, ETC.
C     PRECIP - OBSERVED PRECIPITATION IN INCHES
C     PREWEQV - PREDICTED WATER EQUIVALENT OF THE SNOWPACK IN INCHES
C     RADIN - RADIATION IN IS THE TOTAL INCIDENT SHORT WAVE RADIATION
C     RADLWN - NET LONG WAVE RADIATION IS THE ALGEBRAIC SUM OF THE LONG
C              WAVE RADIATION FROM THE FOREST AND THE LONG WAVE
C              RADIATION LOST BY THE SNOWPACK TO THE CANOPY
C     RADSWN - THE CALORIC INPUT TO THE PACK BY THE NET SHORT WAVE
C              RADIATION
C     REFLECT - THE FRACTION OF RADIATION THAT IS REFLECTED BY THE SNOW
C              AS DERIVED BY SUBROUTINE GETREF
C     SIMTEM1 - AN ARRAY USED PRIMARILY IN SUBROUTINE DIFMOD IN THE
C              SIMULATION OF THE AVERAGE SNOWPACK TEMPERATURE.
C              TO INSURE STABILITY OF THE DIFFUSION MODEL, THE
C              DAY IS PARTITIONED INTO 12 HOUR INTERVALS, AS
C              DISCUSSED IN SUBROUTINE DIFMOD.  THIS ARRAY STORES
C              THE CONDITIONS PRESENT DURING THIS INTERVAL FOR USE
C              IN THE SIMULATION ON THE NEXT INTERVAL.  LOCATION 1
C              STORES THE AVERAGE AIR TEMPERATURE (ASSUMED TO BE
C              THE SURFACE TEMPERATURE OF THE SNOWPACK), LOCATION 2
C              IS THE SNOWPACK TEMPERATURE A  . NODE MIDWAY
C              BETWEEN THE SURFACE AND THE GROUND, AND LOCATION 3 IS
C              THE GROUND TEMPERATURE.
C     SIMTEM2 = THE SNOWPACK TEMPERATURE AT THE MIDDLE NODE FOR THIS
C              INTERVAL, AS SIMULATED BY SUBROUTINE DIFMOD
C     SIMTEM3 = THE AVERAGE SNOWPACK TEMPERATURE FOR THIS INTERVAL, AS
C              DERIVED BY SUBROUTINE DIFMOD
C     SNOMELT - MELT DELIVED IN INCHES FOR THE INTERVAL
C     SOBSEQV - ARRAY FOR STORING THE OBSERVED WATER EQUIVALENT FOR
C              PLOTTING
C     SPRECIP - ARRAY FOR STORING THE PRECIP FOR PLOTTING
C     SPREQV - ARRAY FOR STORING THE PREDICTED WATER EQUIVALENT FOR
C     SUBTITL - ONE CARD SUBTITLE, SIMILAR TO -TITLE-
C     TCOEFF - THE TRANSMISIVITY COEFFICIENT USED TO ESTIMATE THE NET
C              SHORT WAVE RADIATION REACHING THE SNOWPACK.  SEE
C              REIFSNYDER AND LULL, RADIANT ENERGY IN RELATION TO
C              FORESTS, USFS TECH. BUL 1344, 1965.
C     TEMPMAX - THE MAXIMUM TEMPERATURE DURING THE INTERVAL IN DEGREES
C              FARENHEIT
C     TEMPMIN - THE MINIMUM TEMPERATURE DURING THE INTERVAL IN DEGREES
C              FARENHEIT
C     THRSHLD - THE THRESHOLD TEMPERATURE FOR DETERMINING WHETHER OR NOT
C              TO RE-INITIALIZE THE REFLECTIVITY FUNCTION WHEN
C              THERE IS A SNOW EVENT.  IF THE MAXIMUM TEMPERATURE IS
C              GREATER THAN THE THRESHOLD VALUE DO NOT RE-INITIALIZE
C              THE FUNCTION REGARDLESS OF THE PRECIPITATION
C     TITLE - ONE CARD TITLE (IF THE INFORMATION IS CENTERED ON THE CARD
C              IT WILL BE PROPERLY CENTERED ON THE PAGE)
C     TOTPREC - THE ACCUMULATED TOTAL PRECIPITATION IN INCHES
C     USEMEAN = 0, USE MAXIMUM AND MINIMUM TEMPERATURES AS READ
C             = 1, REPLACE THE MAXIMUM AND MINIMUM TEMPERATURES BY THEIR
C              MEAN
C     XMAX - MAXIMUM OBSERVED OR PREDICTED WATER EQUIVALENT, USED FOR
C              SCALING
C-----
      COMMON ACTDATE,ACTUAL(21),AVETEMC,AVETEMF
      COMMON BASTEMF
      COMMON CALAIR,CALDEF,CALORIE,CALSNOW,COVDEN
      COMMON DATE,DATES(3),DEN,DENSITY,DREADY
      COMMON ENGBAL
      COMMON FOOTNOT(16),FREEWAT
      COMMON HOLOCAP
      COMMON IDATE(372),ISNOW,ITABLE
      COMMON KOUNT
      COMMON LASTUSD,LINES
      COMMON NEXTACT
      COMMON OBSWEQV
      COMMON PACKTEM,PARTICE,PASTINT,PLOTOBS,PLOTWE,PRECIP,PREWEQV
      COMMON RADIN,RADLWN,RADSWN,REFLECT
      COMMON SIMTEM1(3),SIMTEM2,SIMTEM3,SNOMELT,SOBSEQV(372),
     1       SPRECIP(372),SPREQV(372),SUBTITL(8)
      COMMON TCOEFF,TEMPMAX,TEMPMIN,THRSHLD,TITLE(8),TOTPREC
      COMMON USEMEAN
      COMMON XMAX
      INTEGER ACTDATE
      INTEGER DATE,DATES,DREADY
      INTEGER FOOTNOT
      INTEGER PASTINT,PLOTOBS,PLOTWE
      INTEGER SUBTITL
      INTEGER TITLE
      INTEGER USEMEAN
      COMMON/CONVERT/FIVE9TH,THIRTY2
      DATA FIVE9TH,THIRTY2/.5555555556,32.0/
C-----INITIALIZE THE MODEL AND READ THE PARAMETER CARDS
   10 CALL INITIAL
C-----READ A DATA CARD
   20 CALL READER (IEND)
C-----A BLANK CARD MAY BE USED TO SEPARATE SETS OF DATA
      IF(IEND.NE.0.OR.DATE.LE.0) GO TO 60
C-----SEE HOW THIS INTERVAL AFFECTS THE SIMULATION
      CALL AFFECTS
C-----IF THE TABLE IS BEING PRINTED, WRITE THIS LINE
      IF(ITABLE) 40,40,30
   30 CALL WRITER
C-----IF THE PLOT IS TO BE DONE, STORE THIS INFORMATION.  THEN GO ON TO
C----- THE NEXT CARD
   40 IF(PLOTWE) 20,20,50
   50 CALL STORE
      GO TO 20
C-----ALL CARDS HAVE BEEN READ, SO PLOT THE SIMULATION AFTER WRITING
C----- THE FOOTNOTES ON THE LAST PAGE
   60 IF(ITABLE.NE.0) WRITE (6,910) FOOTNOT
  910 FORMAT(1H013A10/1X3A10)
      IF(PLOTWE.NE.0) CALL PLOTTER
C-----IF THE END OF FILE HAS NOT BEEN SENSED, GO ON TO THE NEXT SET OF
C----- DATA
      IF(IEND) 70,10,70
   70 STOP
      END
```

Subroutine AFFECTS

```
      SUBROUTINE AFFECTS
C-----DETERMINE THE EFFECTS OF THE DATA FROM THIS CARD
      COMMON ACTDATE,ACTUAL(21),AVETEMC,AVETEMF
      COMMON BASTEMF
      COMMON CALAIR,CALDEF,CALORIE,CALSNOW,COVDEN
      COMMON DATE,DATES(3),DEN,DENSITY,DREADY
      COMMON ENGBAL
      COMMON FOOTNOT(16),FREEWAT
      COMMON HOLOCAP
```

```
      COMMON IDATE(372),ISNOW,ITABLE
      COMMON KOUNT
      COMMON LASTUSD,LINES
      COMMON NEXTACT
      COMMON OBSWEQV
      COMMON PACKTEM,PARTICE,PASTINT,PLOTOBS,PLOTWE,PRECIP,PREWEQV
      COMMON RADIN,RADLWN,RADSWN,REFLECT
      COMMON SIMTEM1(3),SIMTEM2,SIMTEM3,SNOMELT,SOBSEQV(372),
     1       SPRECIP(372),SPREQV(372),SUBTITL(B)
      COMMON TCOEFF,TEMPMAX,TEMPMIN,THRSHLD,TITLE(B),TOTPREC
      COMMON USEMEAN
      COMMON XMAX
      INTEGER ACTDATE
      INTEGER DATE,OATES,DREAOY
      INTEGER FOOTNOT
      INTEGER PASTINT,PLOTOBS,PLOTWE
      INTEGER SUBTITL
      INTEGER TITLE
      INTEGER USEMEAN
      COMMON/CONVERT/FIVE9TH,THIRTY2
C-----START THE ENERGY BALANCE AND SNOWMELT AT ZERO FOR THIS INTERVAL,
C----- BUT ACCUMULATE THE PRECIPITATION
      ISNOW = D
      ENGBAL = D.D
      SNOMELT = D.D
      TOTPREC = TOTPREC + PRECIP
C-----IF A SNOWPACK ALREADY EXISTS, GO FIND THE EFFECT OF THIS INTERVAL
C----- ON THE SNOWPACK
      IF(PREWEQV) 1D,1D,4D
C-----SINCE THERE IS NO SNOWPACK, CHECK TO SEE IF THIS INTERVAL HAS ANY
C----- PRECIPITATION AND IF SO, SEE IF IT IS ALL SNOW
   10 IF(PRECIP) 12D,12D,2D
C-----IF THE MINIMUM TEMPERATURE IS BELOW FREEZING, CONSIDER THE
C----- PRECIPITATION TO BE ALL SNOW
   2D IF(TEMPMIN.LE.THIRTY2.OR.TEMPMAX.LE.BASTEMF) GO TO 6D
C-----SEE IF THE PRECIPITATION IS ALL RAIN OR A MIXTURE ON BARE GROUND
      IF(TEMPMIN - BASTEMF) 9D,3D,30
C-----IT IS ALL RAIN, DO NOT START BUILDING UP THE SNOWPACK
   30 SNOMELT = PRECIP
      GO TO 120
C-----A SNOWPACK EXISTS.  IF THERE IS PRECIPITATION, DETERMINE THE TYPE.
C----- BUT OTHERWISE, JUST GO ON TO COMPUTE THE REFLECTIVITY AND
C----- RADIATION BALANCE
   40 IF(PRECIP) 11D,11D,50
C-----THERE IS PRECIPITATION ON AN EXISTING PACK.  IF IT IS NOT ALL
C----- SNOW, GO SEE IF ANY OF IT WAS SNOW
   5D IF(TEMPMIN.GT.THIRTY2.AND.TEMPMAX.GT.BASTEMF) GO TO 7D
   60 CALL SNOWEO (AMIN1 (AVETEMC,D.O),PRECIP)
      GO TO 11D
C-----SEE WHETHER THE PRECIPITATION ON AN EXISTING PACK WAS ALL RAIN OR
C----- A MIXTURE OF RAIN AND SNOW
   70 IF(TEMPMIN - BASTEMF) 9D,8D,BD
C-----THIS IS A RAIN ON SNOW EVENT.  THE TEMPERATURE FOR COMPUTING THE
C----- DEPLETION OF THE TOTAL CALORIE DEFICIT IS THE DIFFERENCE OF THE
C----- AVERAGE TEMPERATURE AND FREEZING (D.O OEGREES CENTIGRAOE)
   BO CALL RAINEO (AVETEMC,PRECIP)
      GO TO IDD
C-----THIS IS A MIXTURE OF RAIN AND SNOW EVENT
   90 CALL MIXTURE
C-----IF THE PACK WAS ENTIRELY MELTEO, BYPASS COMPUTATION OF THE
C----- REFLECTIVITY AND THE RAOIATION BALANCE
  1DD IF(PREWEQV) I2D,12D,110
C-----GET THE REFLECTIVITY FOR THIS INTERVAL
  110 CALL GETREF
C-----COMPUTE THE RAOIATION BALANCE ANO ITS EFFECT ON THE PACK
      CALL RAOBAL
      RETURN
C-----THERE IS NO SNOWPACK - REOEFINE THE RAOIATION BALANCE TO A
C----- NEGATIVE VALUE TO ASSURE THE PROPER SELECTION OF THE REFLECTIVITY
C----- FUNCTION IN SUBROUTINE GETREF WHEN THERE IS A SNOWPACK
  120 CALORIE = -I.0
      RETURN
      END
```

Subroutine CALIN

```
      SUBROUTINE CALIN (CALORIN)
C-----THIS SUBROUTINE COMPUTES THE EFFECTS OF THE CALORIC INPUT ON THE
C----- SNOWPACK
      COMMON ACTOATE,ACTUAL(21),AVETEMC,AVETEMF
      COMMON BASTEMF
      COMMON CALAIR,CALDEF,CALORIE,CALSNOW,COVOEN
      COMMON OATE,OATES(3),OEN,OENSITY,OREAOY
      COMMON ENGBAL
      COMMON FOOTNOT(I6),FREEWAT
      COMMON HOLOCAP
      COMMON IDATE(372),ISNOW,ITABLE
      COMMON KOUNT
      COMMON LASTUSO,LINES
      COMMON NEXTACT
      COMMON OBSWEQV
      COMMON PACKTEM,PARTICE,PASTINT,PLOTOBS,PLOTWE,PRECIP,PREWEQV
      COMMON RAOIN,RAOLWN,RAOSWN,REFLECT
      COMMON SIMTEM1(3),SIMTEM2,SIMTEM3,SNOMELT,SOBSEQV(372),
     1       SPRECIP(372),SPREQV(372),SUBTITL(B)
      COMMON TCOEFF,TEMPMAX,TEMPMIN,THRSHLO,TITLE(B),TOTPREC
      COMMON USEMEAN
      COMMON XMAX
      INTEGER ACTOATE
      INTEGER OATE,OATES,OREAOY
      INTEGER FOOTNOT
      INTEGER PASTINT,PLOTOBS,PLOTWE
      INTEGER SUBTITL
      INTEGER TITLE
      INTEGER USEMEAN
C-----ADD THESE CALORIES INTO THE ENERGY BALANCE
      ENGBAL = ENGBAL + CALORIN
C-----SEE IF A CALORIE DEFICIT EXISTS IN THE PACK
      COMPARE = CALORIN - CALDEF
      IF(COMPARE) 1D,2D,30
C-----THERE IS A CALORIE DEFICIT, BUT THE INPUT DID NOT COMPLETELY
C----- WIPE IT OUT.  ALL OTHER CONDITIONS ARE UNCHANGED
   10 CALDEF = - COMPARE
C-----I.27 = D.D5 * 2.54
      PACKTEM = COMPARE/(PREWEQV*I.27)
      RETURN
C-----THE CALORIE DEFICIT WAS WIPED OUT, BUT ALL OTHER CONDITIONS ARE
C----- UNCHANGED
   2D CALDEF = D.D
      PACKTEM = D.D
      RETURN
C-----ANY DEFICIT WHICH DID EXIST WAS WIPED OUT.  COMPUTE THE POTENTIAL
C----- MELT FROM THE REMAINING CALORIES (CALORIES/(BD.0 * 2.54))
   3D POTMELT = COMPARE/2D3.2
      CALDEF = D.D
      PACKTEM = D.D
C-----IF THE INPUT WAS ENOUGH TO MELT THE WHOLE PACK, CONTRIBUTE THE
C----- WATER EQUIVALENT TO THE SNOWMELT AND ZERO ALL CONDITIONS
      IF(POTMELT.LT.PARTICE) GO TO 4D
      SNOMELT = SNOMELT + PREWEQV
      PREWEQV = D.D
      PARTICE = O.D
      FREEWAT = D.D
      HOLDCAP = D.D
      RETURN
C-----DEPLETE THE ICE PACK BY THE AMOUNT MELTED AND CONTRIBUTE THAT
C----- AMOUNT TO THE FREE WATER
   4D PARTICE = PARTICE - POTMELT
      FREEWAT = FREEWAT + POTMELT
C-----COMPUTE THE NEW HOLDING CAPACITY OF THE PACK AND COMPARE IT WITH
C----- THE FREE WATER TO SEE IF SNOWMELT IS PRODUCED
      HOLOCAP = D.D4 * PARTICE
      COMPARE = FREEWAT - HOLDCAP
      IF(COMPARE.LE.O.D) RETURN
C-----THE SNOWMELT CONTRIBUTEO IS IN -COMPARE-.  REOUCE THE FREE WATER
C----- TO LEAVE A PRIMEO PACK ANO REOUCE THE PREDICTED WATER EQUIVLAENT
      PREWEQV = PREWEQV - COMPARE
      SNOMELT = SNOMELT + COMPARE
      FREEWAT = HOLDCAP
      RETURN
      ENO
```

Subroutine CALOSS

```
      SUBROUTINE CALOSS (CALOUT)
C-----THIS SUBROUTINE COMPUTES THE EFFECTS OF THE CALORIC LOSS ON THE
C----- SNOWPACK
      COMMON ACTOATE,ACTUAL(21),AVETEMC,AVETEMF
      COMMON BASTEMF
      COMMON CALAIR,CALDEF,CALORIE,CALSNOW,COVOEN
      COMMON OATE,DATES(3),DEN,OENSITY,DREAOY
      COMMON ENGBAL
      COMMON FOOTNOT(16),FREEWAT
      COMMON HOLOCAP
      COMMON IDATE(372),ISNOW,ITABLE
      COMMON KOUNT
      COMMON LASTUSD,LINES
      COMMON NEXTACT
      COMMON OBSWEQV
      COMMON PACKTEM,PARTICE,PASTINT,PLOTOBS,PLOTWE,PRECIP,PREWEQV
      COMMON RAOIN,RADLWN,RAOSWN,REFLECT
      COMMON SIMTEM1(3),SIMTEM2,SIMTEM3,SNOMELT,SOBSEQV(372),
     1       SPRECIP(372),SPREQV(372),SUBTITL(B)
      COMMON TCOEFF,TEMPMAX,TEMPMIN,THRSHLD,TITLE(B),TOTPREC
      COMMON USEMEAN
      COMMON XMAX
      INTEGER ACTOATE
      INTEGER OATE,OATES,OREADY
      INTEGER FOOTNOT
      INTEGER PASTINT,PLOTOBS,PLOTWE
      INTEGER SUBTITL
      INTEGER TITLE
      INTEGER USEMEAN
C-----AOO ALGEBRAICALLY THESE CALORIES INTO THE ENERGY BALANCE
      ENGBAL = ENGBAL + CALOUT
C-----SEE IF THERE IS ANY FREE WATER IN THE PACK.  IF NOT, THE LOSS IS
C----- JUST CONTRIBUTEO TO THE CALORIC OEFICIT OF THE SNOWPACK.
C----- REMEMBER THAT -CALOUT- IS NEGATIVE
      IF(FREEWAT.GT.D.O) GO TO 10
      CALOEF = CALOEF - CALOUT
      GO TO 5D
C-----COMPUTE THE CALORIC LOSS NECESSARY TO FREEZE ALL OF THE FREE WATER
C----- (FREE WATER * BO.0 * 2.54)
   1D CALNEEO = FREEWAT * 203.2
C-----NOW COMPARE THAT NECESSARY LOSS WITH THE ACTUAL LOSS.  IF THEY ARE
C----- THE SAME, THE FREE WATER IS WIPEO OUT BUT NO OTHER CONOITIONS ARE
C----- ALTEREO
      COMPARE = CALOUT + CALNEEO
      IF(COMPARE) 2D,3D,40
C-----THE LOSS WAS MORE THAN ENOUGH TO FREEZE IT.  THE BALANCE CREATES
C----- AN ENERGY OEFICIT IN THE PACK ANO THE FREE WATER IS WIPEO OUT
   20 CALOEF = - COMPARE
   30 PARTICE = PARTICE + FREEWAT
      FREEWAT = O.D
      GO TO 50
C-----ONLY PART OF THE FREE WATER FROZE.  COMPUTE THE BALANCE REMAINING
C----- BALANCE = EXISTING FREE WATER - AMOUNT FROZEN, WHERE
C----- AMOUNT FROZEN = CALORIES/(BD.D * 2.54)
   40 FROZEN = - CALOUT/203.2
```

```
      PARTICE = PARTICE + FROZEN
      FREEWAT = FREEWAT - FROZEN
      RETURN
C-----COMPUTE THE NEW PACK TEMPERATURE ANO HOLO CAPACITY
   50 PACKTEM = -CALOEF/(PREWEQV*1.27)
      HOLOCAP = 0.04 * PARTICE
      RETURN
      ENO
```

Subroutine DIFMOD

```
      SUBROUTINE OIFMOO
C-----THIS SUBROUTINE WAS OERIVEO FROM PROGRAM SIMTEM, A SNOWPACK
C----- TEMPERATURE OIFFUSION MOOEL OEVELOPEO BY LEAF (1970 STUOY PLAN
C----- FS-RM-1602, NO. 224, RMF+RES). USING THE AVERAGE SURFACE TEMP
C----- ANO THE GROUNO TEMP AS BOUNOARY CONOITIONS, THE NEW AVERAGE
C----- SNOWPACK TEMPERATURE IS CALCULATEO
      COMMON ACTOATE,ACTUAL(21),AVETEMC,AVETEMF
      COMMON BASTEMF
      COMMON CALAIR,CALOEF,CALORIE,CALSNOW,COVOEN
      COMMON OATE,OATES(3),OEN,OENSITY,OREAOY
      COMMON ENGBAL
      COMMON FOOTNOT(16),FREEWAT
      COMMON HOLOCAP
      COMMON IOATE(372),ISNOW,ITABLE
      COMMON KOUNT
      COMMON LASTUSO,LINES
      COMMON NEXTACT
      COMMON OBSWEQV
      COMMON PACKTEM,PARTICE,PASTINT,PLOTOBS,PLOTWE,PRECIP,PREWEQV
      COMMON RAOIN,RAOLWN,RAOSWN,REFLECT
      COMMON SIMTEM1(3),SIMTEM2,SIMTEM3,SNOMELT,SOBSEQV(372),
     1       SPRECIP(372),SPREQV(372),SUBTITL(B)
      COMMON TCOEFF,TEMPMAX,TEMPMIN,THRSHLO,TITLE(B),TOTPREC
      COMMON USEMEAN
      COMMON XMAX
      INTEGER ACTOATE
      INTEGER OATE,OATES,OREAOY
      INTEGER FOOTNOT
      INTEGER PASTINT,PLOTOBS,PLOTWE
      INTEGER SUBTITL
      INTEGER TITLE
      INTEGER USEMEAN
C-----
C-----OICTIONARY
C
C     CALOM - THE CALORIC INPUT OR LOSS AS OERIVEO BY THE OIFFUSION
C             MOOEL
C     CONST1 - THE FIRST CONSTANT IN THE EQUATION FOR THE SIMULATION
C     CONST2 - THE SECONO CONSTANT IN THE EQUATION FOR THE SIMULATION
C     __H - THE OISTANCE BETWEEN NOOES (CORRESPONOS TO THE -H- IN THE
C             STUOY PLAN)
C-----
      COMMON/CONVERT/FIVE9TH,THIRTY2
C-----IF THIS IS THE OATE OF THE ACTUAL OR OBSERVEO PACK TEMPERATURES,
C----- BYPASS THE SIMULATION ANO USE THE OBSERVEO AVERAGE
      IF(OATE - ACTOATE) 1D,100,1D
C-----IF THE OENSITY WAS NOT SPECIFIEO ON THE INPUT CARO, COMPUTE IT AS
C----- A FUNCTION OF THE WATER EQUIVALENT. (THE FUNCTION WAS OERIVED
C----- FROM OBSERVEO CONOITIONS ON THE FRASER EXPERIMENTAL FOREST)
   10 IF(OEN) 20,2D,30
   20 OENSITY = (EXP((0.D179 * PREWEQV) + 3.02))/1D0.0
      GO TO 40
   30 OENSITY = OEN
C-----COMPUTE THE OISTANCE BETWEEN THE TWO NODES IN CENTIMETERS
C-----OEPTH = PREWEQV/OENSITY
C-----H = (OEPTH/2)*2.54
   40 H = (PREWEQV/DENSITY) * 1.27
C-----THE THERMAL OIFFUSIVITY IS CALCULATEO FROM THE FUNCTION
C----- KV = 0.01/((2.751 - OENSITY)* 0.4B). MATHEMATICAL STABILITY
C----- REQUIRES THAT THE VALUE OF THE QUANTITY (INTERVAL IN SECONOS *
C----- KV/H**2) BE LESS THAN 0.5. WHEN A 24 HOUR INTERVAL IS USEO, THE
C----- SNOW OEPTH MUST EXCEEO 30 INCHES (20 PERCENT OENSITY) TO ACHIEVE
C----- STABILITY. IN OROER TO INSURE STABILITY WITH SOMEWHAT SHALLOWER
C----- PACKS (ABOUT 1B INCHES), THE OAY IS OIVIOEO INTO 2 TIME INTERVALS
C----- OF 12 HOURS (43200 SECONOS)
C-----CONST1 = (43200 * 0.01/((2.751 - OENSITY) * 0.4B))/H**2
      CONST1 = 900.0/((2.751 - OENSITY)*H*H)
C-----THE MINIMUM WATER EQUIVALENT WHICH WILL ACHIEVE STABILITY USING
C----- THE ABOVE OENSITY FUNCTION IS 4.7 INCHES
      IF(CONST1 - 0.5) 60,50,50
C-----THE MOOEL IS UNSTABLE - INOICATE THAT IT IS NOT REAOY FOR USE NOW.
C----- (IT MAY BE INITIALIZEO AGAIN BY AN OBSERVEO PACK TEMPERATURE CARO
C----- ANO STABILITY WILL BE ASCERTAINEO FROM THE WATER EQUIVALENT AT
C----- THAT TIME)
   50 OREAOY = O
      RETURN
C-----GET THE SECONO CONSTANT
   60 CONST2 = 1.0 - CONST1 - CONST1
C-----PERFORM THE SIMULATION IN TWO PARTS (ONE FOR EACH 12 HOUR PERIOO).
C----- -SIMTEM1- HOLOS THE THREE TEMPERATURES FROM THE PREVIOUS INTERVAL
C----- THAT ARE NEEOEO TO SIMULATE SIMTEM2, THE NOOE AT THE CENTER OF
C----- THE PACK. SIMULATE THE FIRST 12 HOURS NOW
      SIMTEM2 = (CONST1 * (SIMTEM1(1) + SIMTEM1(3))) + (CONST2 * SIMTEM1
     1(2))
C-----THE AVERAGE SNOWPACK TEMPERATURE IS THE AVERAGE OF THE 2 NOOES
C----- (MIOOLE ANO GROUNO) IN BOTH INTERVALS. GROUNO TEMPERATURE IS
C----- CONSTANT, SO START THE AVERAGE NOW
      SIMTEM3 = SIMTEM1(3) + SIMTEM1(3) + SIMTEM2
C-----RESET -SIMTEM1- TO THE TEMPERATURES OF THE INTERVAL JUST SIMULATEO
C----- FOR USE IN THE SECONO 12 HOUR INTERVAL SIMULATION. THE SURFACE
C----- AIR TEMPERATURE IS SPLIT INTO A LOW AVERAGE ( (MEAN+MIN)/2 ) ANO
C----- A HIGH AVERAGE ( (MEAN+MAX)/2 ) FOR USE WITH THE TWELVE HOUR
C----- INTERVALS. USE THE LOW AVERAGE NOW
      SIMTEM1(1) = AMIN1 (0.0,(((TEMPMIN-THIRTY2)*FIVE9TH)+AVETEMC)/2.0)
      SIMTEM1(2) = SIMTEM2
C-----SIMULATE THE SECONO 12 HOURS ANO COMPUTE THE AVERAGE SNOWPACK
C----- TEMPERATURE
      SIMTEM2 = (CONST1 * (SIMTEM1(1) + SIMTEM1(3))) + (CONST2 * SIMTEM1
     1(2))
      SIMTEM3 = (SIMTEM3 + SIMTEM2)/4.0
C-----RESET -SIMTEM1- USING THE HIGH AVERAGE FOR USE ON THE FIRST
C----- INTERVAL OF THE NEXT OAY
      SIMTEM1(1) = AMIN1 (0.0,(((TEMPMAX-THIRTY2)*FIVE9TH)+AVETEMC)/2.0)
      SIMTEM1(2) = SIMTEM2
C-----CHECK TO SEE IF THE GROUNO TEMPERATURE SHOULO BE RAISEO
      IF(SIMTEM3 + 1.5) 100,B0,70
   70 IF(SIMTEM3 + 0.5) B0,90,90
   B0 IF(SIMTEM1(3).LT.-0.5) SIMTEM1(3) = -0.5
      RETURN
   90 SIMTEM1(3) = D.0
  100 RETURN
      ENO
```

Subroutine GETREF

```
      SUBROUTINE GETREF
C-----GET THE REFLECTIVITY
C-----
C-----OICTIONARY
C
C     REFACUM - A REFLECTIVITY FUNCTION FOR THE SNOWPACK OURING THE
C               ACCUMULATION PHASE OF THE SNOWPACK
C     REFMELT - A REFLECTIVITY FUNCTION FOR THE SNOWPACK OURING THE
C               MELT PHASE OF THE SNOWPACK
C-----
      COMMON ACTOATE,ACTUAL(21),AVETEMC,AVETEMF
      COMMON BASTEMF
      COMMON CALAIR,CALOEF,CALORIE,CALSNOW,COVOEN
      COMMON DATE,OATES(3),OEN,DENSITY,OREAOY
      COMMON ENGBAL
      COMMON FOOTNOT(16),FREEWAT
      COMMON HOLOCAP
      COMMON IOATE(372),ISNOW,ITABLE
      COMMON KOUNT
      COMMON LASTUSO,LINES
      COMMON NEXTACT
      COMMON OBSWEQV
      COMMON PACKTEM,PARTICE,PASTINT,PLOTOBS,PLOTWE,PRECIP,PREWEQV
      COMMON RAOIN,RAOLWN,RAOSWN,REFLECT
      COMMON SIMTEM1(3),SIMTEM2,SIMTEM3,SNOMELT,SOBSEQV(372),
     1       SPRECIP(372),SPREQV(372),SUBTITL(B)
      COMMON TCOEFF,TEMPMAX,TEMPMIN,THRSHLD,TITLE(B),TOTPREC
      COMMON USEMEAN
      COMMON XMAX
      INTEGER ACTOATE
      INTEGER OATE,OATES,OREAOY
      INTEGER FOOTNOT
      INTEGER PASTINT,PLOTOBS,PLOTWE
      INTEGER SUBTITL
      INTEGER TITLE
      INTEGER USEMEAN
      OIMENSION REFACUM(15),REFMELT(15)
      OATA REFACUM/.BD, .77, .75, .72, .70, .69, .6B, .67, .66, .65,
     1 .64, .63, .62, .61, .6D/
      OATA REFMELT/.72, .65, .60, .5B, .56, .54, .52, .5D, .4B, .46,
     1 .44, .43, .42, .41, .40/
C-----INCREASE THE INTERVAL COUNTER BY 1 ANO SEE IF THERE WAS ANY SNOW
      PASTINT = PASTINT + 1
      IF(ISNOW) 10,10,B0
C-----USE THE SAME FUNCTION AS LAST TIME
   10 IF(LASTUSD) 20,20,50
C-----ACCUMULATION PHASE - AFTER 15 OAYS, USE THE MELT FUNCTION
C----- STARTING AT THE FOURTH OAY
   20 IF(PASTINT - 15) 30,30,40
   30 REFLECT = REFACUM(PASTINT)
      RETURN
   40 PASTINT = 4
      LASTUSO = 1
      GO TO 70
C-----MELT FUNCTION - AFTER 15 OAYS, USE A CONSTANT 40 PERCENT
   50 IF(PASTINT - 15) 70,70,60
   60 PASTINT = 15
   70 REFLECT = REFMELT(PASTINT)
      RETURN
C-----THERE IS NEW SNOW - OETERMINE IF THE FUNCTION IS TO BE RE-
C----- INITIALIZEO
   B0 IF(TEMPMAX - THRSHLO) 90,90,10
C-----IT IS, SO SEE WHICH FUNCTION IS TO BE USEO
   90 PASTINT = O
      IF(PACKTEM) 100,110,110
  100 REFLECT = 0.91
      LASTUSO = 0
      RETURN
C-----THE PACK IS ISOTHERMAL, BUT IF THE ENERGY BALANCE FROM THE
C----- PREVIOUS INTERVAL WAS NEGATIVE, USE THE ACCUMULATION PHASE
C----- FUNCTION ANYWAY
  110 IF(CALORIE) 100,120,120
  120 REFLECT = 0.81
      LASTUSO = 1
      RETURN
      END
```

Subroutine INITIAL

```
      SUBROUTINE INITIAL
C-----READ THE PARAMETERS ANO INITIALIZE THE MELT MOOEL
```

```
      COMMON ACTDATE,ACTUAL(21),AVETEMC,AVETEMF
      COMMON BASTEMF
      COMMON CALAIR,CALDEF,CALORIE,CALSNOW,COVDEN
      COMMON DATE,DATES(3),DEN,DENSITY,DREADY
      COMMON ENGBAL
      COMMON FOOTNOT(16),FREEWAT
      COMMON HOLDCAP
      COMMON IDATE(372),ISNOW,ITABLE
      COMMON KOUNT
      COMMON LASTUSD,LINES
      COMMON NEXTACT
      COMMON OBSWEQV
      COMMON PACKTEM,PARTICE,PASTINT,PLOTOBS,PLOTWE,PRECIP,PREWEQV
      COMMON RADIN,RADLWN,RADSWN,REFLECT
      COMMON SIMTEM1(3),SIMTEM2,SIMTEM3,SNOMELT,SOBSEQV(372),
     1       SPRECIP(372),SPREQV(372),SUBTITL(8)
      COMMON TCOEFF,TEMPMAX,TEMPMIN,THRSHLD,TITLE(8),TOTPREC
      COMMON USEMEAN
      COMMON XMAX
      INTEGER ACTDATE
      INTEGER DATE,DATES,DREADY
      INTEGER FOOTNOT
      INTEGER PASTINT,PLOTOBS,PLOTWE
      INTEGER SUBTITL
      INTEGER TITLE
      INTEGER USEMEAN
C-----ESTABLISH THE STANDARD BASE TEMPERATURE
      BASTEMF = 35.0
C-----INITIALIZE THOSE VARIABLES WHICH ARE NOT READ IN OR OTHERWISE
C----- INITIALIZED BEFORE BEING USED
      FREEWAT = 0.0
      HOLDCAP = 0.0
      SUM = 0.0
      TOTAL = 0.0
      XMAX = 0.0
      DREADY = 0
      ISNOW = 0
      KOUNT = 0
      LASTUSD = 0
      PASTINT = 0
      LINES = 999
C-----START THE RADIATION BALANCE WITH A NEGATIVE VALUE FOR POSSIBLE USE
C----- BY SUBROUTINE GETREF IN DETERMINING WHICH REFLECTIVITY FUNCTION
C----- TO USE
      CALORIE = -1.0
C-----READ THE INSTRUCTION PARAMETERS AND THE CONTROLS ON THE MODEL
      READ (5,910) ITABLE,PLOTWE,PLOTOBS,USEMEAN,TCOEFF,COVDEN,PACKTEM,
     1 PREWEQV,THRSHLD
  910 FORMAT(4I1,1X,5F5.2)
      IF(EOF(5)) 10,10,20
C-----READ THE TITLE, SUBTITLE AND FOOTNOTE CARDS
   10 READ (5,920) TITLE,SUBTITL,FOOTNOT
  920 FORMAT(8A10)
C-----INITIALIZE THE ICE CONTENT AND ACCUMULATED PRECIPITATION
      PARTICE = PREWEQV
      TOTPREC = PREWEQV
C-----CALCULATE THE CALORIE DEFICIT FROM THE PACK TEMPERATURE
C-----CALDEF = - (PACKTEM * 80) * (PREWEQV * 2.54) / 160
      CALDEF = - PACKTEM * PREWEQV * 1.27
      RETURN
   20 STOP
      END
```

Subroutine LINK

```
      SUBROUTINE LINK (IRETURN)
C-----THIS SUBROUTINE IS THE INTERFACE BETWEEN THE RADIATION BALANCE
C----- (SUBROUTINE RADBAL) AND THE DIFFUSION MODEL (SUBROUTINE DIFMOD)
      COMMON ACTDATE,ACTUAL(21),AVETEMC,AVETEMF
      COMMON BASTEMF
      COMMON CALAIR,CALDEF,CALORIE,CALSNOW,COVDEN
      COMMON DATE,DATES(3),DEN,DENSITY,DREADY
      COMMON ENGBAL
      COMMON FOOTNOT(16),FREEWAT
      COMMON HOLDCAP
      COMMON IDATE(372),ISNOW,ITABLE
      COMMON KOUNT
      COMMON LASTUSD,LINES
      COMMON NEXTACT
      COMMON OBSWEQV
      COMMON PACKTEM,PARTICE,PASTINT,PLOTOBS,PLOTWE,PRECIP,PREWEQV
      COMMON RADIN,RADLWN,RADSWN,REFLECT
      COMMON SIMTEM1(3),SIMTEM2,SIMTEM3,SNOMELT,SOBSEQV(372),
     1       SPRECIP(372),SPREQV(372),SUBTITL(8)
      COMMON TCOEFF,TEMPMAX,TEMPMIN,THRSHLD,TITLE(8),TOTPREC
      COMMON USEMEAN
      COMMON XMAX
      INTEGER ACTDATE
      INTEGER DATE,DATES,DREADY
      INTEGER FOOTNOT
      INTEGER PASTINT,PLOTOBS,PLOTWE
      INTEGER SUBTITL
      INTEGER TITLE
      INTEGER USEMEAN
      COMMON/CONVERT/FIVE9TH,THIRTY2
C-----SEE IF THE RADIATION BALANCE IS AN ENERGY LOSS OR GAIN
      IF(CALORIE) 10,10,80
C-----THERE WAS A LOSS.  IF THIS IS STILL WINTER (NO FREEWATER), JUST
C----- GO AHEAD AND USE THE DIFFUSION MODEL
   10 IF(FREEWAT) 20,20,50
C-----USE THE DIFFUSION MODEL TO SIMULATE THE CURRENT AVERAGE SNOWPACK
C-----TEMPERATURE
   20 CALL DIFMOD
      IF(DREADY) 40,40,30
C-----NOW MAKE ANY NECESSARY ADJUSTMENTS IN THE RADIATION BALANCE TO
C----- CAUSE THE PACK TEMPERATURE TO BE THE SAME AS -SIMTEM3-.  START BY
C----- GETTING THE DIFFERENCE BETWEEN THE LAST PACK TEMPERATURE AND THIS
C----- ONE, THEN CONVERT IT TO CALORIES
   30 CALOM = (SIMTEM3 - PACKTEM) * PREWEQV * 1.27
C-----ADJUST THE LONG WAVE PORTION OF THE RADIATION BALANCE BY THE
C----- DIFFERENCE BETWEEN THE CALORIES DERIVED FROM THE DIFFUSION MODEL
C----- AND THE ENERGY BALANCE
      RADLWN = RADLWN + (CALOM - CALORIE)
      CALORIE = CALOM
   40 IRETURN = 0
      RETURN
C-----THE LOSS IS USED TO FREEZE PART OR ALL OF THE FREE WATER, BUT IT
C----- MAY NOT CREATE COLD CONTENT.  IF IT WOULD CREATE COLD CONTENT,
C----- RE-INITIALIZE THE DIFFUSION MODEL TO 0 AND ADJUST THE ENERGY
C----- BALANCE ACCORDINGLY
   50 CALL CALOSS (CALORIE)
      IF(FREEWAT - 0.5) 60,60,70
   60 SIMTEM1(1) = AMIN1 (AVETEMC,0.0)
      SIMTEM1(2) = 0.0
      SIMTEM1(3) = 0.0
      DREADY = 1
C-----MAKE ANY NECESSARY ADJUSTMENTS TO THE ENERGY BALANCE TO COMPENSATE
C----- FOR THE COLD CONTENT THAT WOULD HAVE BEEN GENERATED BY THIS LOSS
C----- AND ZERO THE COLD CONTENT
      CALORIE = CALORIE + CALDEF
      RADLWN = RADLWN + CALDEF
      PARTICE = PARTICE + FREEWAT
      PREWEQV = PREWEQV + FREEWAT
      FREEWAT = 0.0
      CALDEF = 0.0
      PACKTEM = 0.0
   70 IRETURN = 1
      RETURN
C-----THERE IS CALORIC INPUT TO THE PACK.  CHECK TO SEE IF CONDITIONS
C----- INDICATE THAT THE DIFFUSION MODEL SHOULD BE TURNED OFF AND THE
C----- ENERGY BALANCE USED FOR SPRINGTIME SIMULATION.  CONSIDER FIRST
C----- ANY COLD CONTENT (INCLUDING THAT OF THE PREVIOUS DAY AND ANY
C----- CREATED BY A SNOW EVENT ON THIS DAY).  IF THERE IS COLD CONTENT,
C----- CHECK THE AVERAGE AIR TEMPERATURE AND THE SNOWPACK TEMPERATURE
C----- FROM THE PREVOUS DAY FOR ARBITRARILY CHOSEN SPRINGTIME CONDITIONS
C----- AND IF ALL ARE NOT SATISFIED, GO AHEAD AND USE THE DIFFUSION
C----- MODEL
   80 IF(CALDEF) 170,170,90
   90 IF(AVETEMC.LE.0.0.OR.PACKTEM.LE.-0.7) GO TO 20
C-----SINCE SPRINGTIME CONITIONS PREVAIL, RECOMPUTE THE BACK RADIATION
C----- AND THE NET RADIATION BALANCE (REMEMBER, IF THERE IS SNOW, THE
C----- LONGWAVE IS ASSUMED TO BE ZERO, SO THERE WOULD BE NO NEED TO MAKE
C----- ANY ADJUSTMENTS)
      IF(ISNOW) 100,100,140
  100 USE = (TEMPMIN - THIRTY2) * FIVE9TH
      IF(USE.GT.0.0) USE = 0.0
      CALSNOW = 1.17E-7 * ((USE + 273.16) ** 4)
      IF(PRECIP) 110,110,120
  110 RADLWN = ((1.0 - COVDEN) * ((0.757 * CALAIR) - CALSNOW)) + (COVDEN
     1 * (CALAIR - CALSNOW))
      GO TO 130
  120 RADLWN = CALAIR - CALSNOW
  130 CALORIE = RADSWN + RADLWN
C-----RE-INITIALIZE THE DIFFUSION MODEL TO THESE CONDITIONS (BUT IF THE
C----- INPUT IS MORE THAN ENOUGH TO WIPE OUT THE CALORIE DEFICIT, JUST
C----- LET IT BRING THE PACK TO ISOTHERMAL.  IN THIS WAY, TWO CONSECU-
C----- TIVE DAYS OF INPUT ARE REQUIRED TO GENERATE FREE WATER)
  140 ACTDATE = DATE
      COMPARE = CALORIE - CALDEF
      IF(COMPARE) 160,150,150
C-----INITIALIZE THE DIFFUSION MODEL TO ISOTHERMAL CONDITIONS
  150 SIMTEM1(1) = 0.0
      SIMTEM1(2) = 0.0
      SIMTEM1(3) = 0.0
      SIMTEM3 = 0.0
      GO TO 20
C-----REDEFINE THE SURFACE TEMPERATURE AND COMPUTE THE NEW AVERAGE PACK
C----- TEMPERATURE.  THEN COMPUTE THE MIDDLE NODE AS A FUNCTION OF THAT
C----- AVERAGE, THE SURFACE TEMPERATURE AND THE GROUND TEMPERATURE
C----- (WHICH REMAINED UNCHANGED)
  160 SIMTEM1(1) = AMIN1 (0.0,AVETEMC)
      SIMTEM3 = COMPARE/(PREWEQV * 1.27)
      SIMTEM1(2) = (3.0 * SIMTEM3) - SIMTEM1(1) - SIMTEM1(3)
      SIMTEM1(3) = 0.0
      GO TO 20
C-----THERE IS INPUT TO THE PACK AND THE PACK IS ALREADY ISOTHERMAL.  (IF
C----- THIS ENERGY WILL CREATE AT LEAST 0.05 INCH (ARBITRARY AMOUNT) OF
C----- FREE WATER, TURN THE DIFFUSION MODEL OFF AND LET THE ENERGY
C----- BALANCE TAKE ITS COURSE
  170 IF(FREEWAT + (CALORIE/203.2) - 0.05) 150,180,180
  180 DREADY = 0
      IRETURN = 0
      RETURN
      END
```

Subroutine MIXTURE

```
      SUBROUTINE MIXTURE
C----THIS SUBROUTINE CONTROLS THE COMPUTATIONS FOR A PRECIPITATION
C----- EVENT THAT IS A MIXTURE OF SNOW AND RAIN
C-----
C-----DICTIONARY
C-----
C      AMTSNOW - THE AMOUNT OF PRECIPITATION OCCURRING AS SNOW (INCHES)
C      TFORAIN - THE TEMPERATURE FOR COMPUTING THE DEPLETION OF THE TOTAL
C                CALORIE DEFICIT CAUSED BY THE RAIN (DEGREES C)
C      TFORSNO - THE TEMPERATURE FOR COMPUTING THE CONTRIBUTION OF THE
C                SNOW TO THE TOTAL CALORIE DEFICIT (DEGREES C)
```

```
C-----
      COMMON ACTOATE,ACTUAL(21),AVETEMC,AVETEMF
      COMMON BASTEMF
      COMMON CALAIR,CALOEF,CALORIE,CALSNOW,COVOEN
      COMMON OATE,OATES(3),OEN,OENSITY,OREAOY
      COMMON ENGBAL
      COMMON FOOTNOT(16),FREEWAT
      COMMON HOLOCAP
      COMMON IOATE(372),ISNOW,ITABLE
      COMMON KOUNT
      COMMON LASTUSO,LINES
      COMMON NEXTACT
      COMMON OBSWEQV
      COMMON PACKTEM,PARTICE,PASTINT,PLOTOBS,PLOTWE,PRECIP,PREWEQV
      COMMON RAOIN,RAOLWN,RAOSWN,REFLECT
      COMMON SIMTEM1(3),SIMTEM2,SIMTEM3,SNOMELT,SOBSEQV(372),
     1       SPRECIP(372),SPREQV(372),SUBTITL(B)
      COMMON TCOEFF,TEMPMAX,TEMPMIN,THRSHLO,TITLE(B),TOTPREC
      COMMON USEMEAN
      COMMON XMAX
      INTEGER ACTOATE
      INTEGER OATE,OATES,DREAOY
      INTEGER FOOTNOT
      INTEGER PASTINT,PLOTOBS,PLOTWE
      INTEGER SUBTITL
      INTEGER TITLE
      INTEGER USEMEAN
      COMMON/CONVERT/FIVE9TH,THIRTY2
C-----COMPUTE THE AMOUNT OF PRECIPITATION OCCURRING AS SNOW BY
C----- AMOUNT SNOW = P * (1.0 - B/A), WHERE
C----- P = PRECIPITATION IN INCHES
C----- B = OAILY MAXIMUM TEMPERATURE - BASE TEMPERATURE (OEGREES F)
C----- A = OAILY MAXIMUM TEMPERATURE - MINIMUM TEMPERATURE (OEGREES F)
      B = TEMPMAX - BASTEMF
      A = TEMPMAX - TEMPMIN
      AMTSNOW = PRECIP * (1.0 - (B/A))
C-----NOW COMPUTE THE AVERAGE TEMPERATURES (OEGREES C) WHICH PROOUCE
C----- SNOW AND RAIN
      TFORSNO = (((TEMPMIN + BASTEMF) * 0.5) - THIRTY2) * FIVE9TH
      TFORAIN = (((TEMPMAX + BASTEMF) * 0.5) - THIRTY2) * FIVE9TH
C-----COMPUTE THE EFFECT OF THE SNOW ON THE SNOWPACK
      CALL SNOWEO (TFORSNO,AMTSNOW)
C-----COMPUTE THE EFFECT OF THAT PORTION OF THE PRECIPITATION OCCURRING
C----- AS RAIN ON THE SNOWPACK
      CALL RAINEO (TFORAIN,PRECIP-AMTSNOW)
      RETURN
      ENO
```

Subroutine PLOTTER

```
      SUBROUTINE PLOTTER
C-----THIS SUBROUTINE CONTROLS THE PLOTTING OF THE MOOEL OUTPUT
      COMMON ACTOATE,ACTUAL(21),AVETEMC,AVETEMF
      COMMON BASTEMF
      COMMON CALAIR,CALOEF,CALORIE,CALSNOW,COVOEN
      COMMON OATE,OATES(3),OEN,OENSITY,OREAOY
      COMMON ENGBAL
      COMMON FOOTNOT(16),FREEWAT
      COMMON HOLOCAP
      COMMON IOATE(372),ISNOW,ITABLE
      COMMON KOUNT
      COMMON LASTUSO,LINES
      COMMON NEXTACT
      COMMON OBSWEQV
      COMMON PACKTEM,PARTICE,PASTINT,PLOTOBS,PLOTWE,PRECIP,PREWEQV
      COMMON RAOIN,RAOLWN,RAOSWN,REFLECT
      COMMON SIMTEM1(3),SIMTEM2,SIMTEM3,SNOMELT,SOBSEQV(372),
     1       SPRECIP(372),SPREQV(372),SUBTITL(B)
      COMMON TCOEFF,TEMPMAX,TEMPMIN,THRSHLO,TITLE(B),TOTPREC
      COMMON USEMEAN
      COMMON XMAX
      INTEGER ACTOATE
      INTEGER OATE,OATES,OREAOY
      INTEGER FOOTNOT
      INTEGER PASTINT,PLOTOBS,PLOTWE
      INTEGER SUBTITL
      INTEGER TITLE
      INTEGER USEMEAN
      OIMENSION LEGENO(B)
      OATA LEGENO/ 80H1 = PREOICTEO WATER EQUIVALENT, 2 = OBSERVEO WATER
     1 EQUIVALENT, 3 = PRECIPITATION/
C-----TURN OFF THE AUTOMATIC PAGE EJECT
      WRITE (6,910)
  910 FORMAT(*Q*)
C-----INITIALIZE THE PLOT ROUTINE
      CALL TSPLOT (3,0,0,0,0,0,0,XMAX,0.0,IOATE(1),7,-1)
C-----PLOT ONE LINE FOR EACH INTERVAL
      DO 10 I = 1,KOUNT
   10 CALL TSPLOT (3,SPREQV(I),SOBSEQV(I),SPRECIP(I),D.D,0.0,0.0,XMAX,
     1 0.0,IOATE(I),7,1)
C-----WRITE THE TITLE ANO OTHER IOENTIFYING INFORMATION
      WRITE (6,920) TITLE,SUBTITL,TCOEFF,COVOEN,LEGENO,FOOTNOT
  920 FORMAT(1HD26XBA10/27XBA10/* TRANSMISIVITY COEFFICIENT =*F4.2,74X
     1 *COVER OENSITY =*F4.2/1H0,19X*PLOT LEGENO -- *BA10//1H013A10/1X
     2 3A10)
C-----TURN THE AUTOMATIC PAGE EJECT BACK ON
      WRITE (6,930)
  930 FORMAT(*R*)
      RETURN
      ENO
```

Subroutine RADBAL

```
      SUBROUTINE RAOBAL
C-----THIS SUBROUTINE COMPUTES THE RAOIATION BALANCE AND TRANSFERS
C----- CONTROL TO THE OIFFUSION MOOEL IF IT IS NEEOEO
C-----
C-----OICTIONARY
C-----
C     SNOCAN - THE LONGWAVE RAOIATION BALANCE BETWEEN THE SNOW ANO THE
C              CANOPY
C     SNOSKY - THE LONGWAVE RAOIATION BALANCE BETWEEN THE SNOW ANO THE
C              SKY
      COMMON ACTOATE,ACTUAL(21),AVETEMC,AVETEMF
      COMMON BASTEMF
      COMMON CALAIR,CALDEF,CALORIE,CALSNOW,COVOEN
      COMMON DATE,OATES(3),OEN,OENSITY,OREAOY
      COMMON ENGBAL
      COMMON FOOTNOT(16),FREEWAT
      COMMON HOLOCAP
      COMMON IDATE(372),ISNOW,ITABLE
      COMMON KOUNT
      COMMON LASTUSO,LINES
      COMMON NEXTACT
      COMMON OBSWEQV
      COMMON PACKTEM,PARTICE,PASTINT,PLOTOBS,PLOTWE,PRECIP,PREWEQV
      COMMON RAOIN,RAOLWN,RAOSWN,REFLECT
      COMMON SIMTEM1(3),SIMTEM2,SIMTEM3,SNOMELT,SOBSEQV(372),
     1       SPRECIP(372),SPREQV(372),SUBTITL(B)
      COMMON TCOEFF,TEMPMAX,TEMPMIN,THRSHLO,TITLE(B),TOTPREC
      COMMON USEMEAN
      COMMON XMAX
      INTEGER ACTOATE
      INTEGER OATE,OATES,OREAOY
      INTEGER FOOTNOT
      INTEGER PASTINT,PLOTOBS,PLOTWE
      INTEGER SUBTITL
      INTEGER TITLE
      INTEGER USEMEAN
      COMMON/CONVERT/FIVE9TH,THIRTY2
C-----COMPUTE THE CALORIC INPUT FROM NET SHORT WAVE RAOIATION AS A
C----- FUNCTION OF THE REFLECTIVITY
      RAOSWN = RAOIN * (1.0 - REFLECT) * TCOEFF
C-----IF THE PRECIP WAS SNOW, THE NET LONG WAVE RAOIATION BALANCE IS
C----- ASSUMEO TO BE ZERO
      IF(ISNOW) 20,20,10
   10 RADLWN = 0.0
      GO TO 50
C-----TO COMPUTE THE LONG WAVE RADIATION COMPONENTS, CONVERT THE AIR
C----- ANO SNOW TEMPERATURES TO POTENTIAL CALORIES BY THE STEFAN -
C----- BLOTZMANN FUNCTION, CALORIES = S * (T ** 4), WHERE
C----- S = 1.17E-7 CAL/((CM**2)(OEGREES KELVIN)**4), ANO
C----- T = ABSOLUTE TEMPERATURE (OEGREES KELVIN)
   20 CALAIR = 1.17E-7 * ((AVETEMC + 273.16) ** 4)
      USE = AVETEMC
C-----IF THE SNOWPACK IS ISOTHERMAL, USE THE MINIMUM TEMPERATURE FOR
C----- COMPUTING THE BACK RAOIATION
      IF(CALOEF.EQ.D.O) USE = (TEMPMIN - THIRTY2) * FIVE9TH
C-----UNOER NO CIRCUMSTANCES MAY THE TEMPERATURE FOR COMPUTING THE BACK
C----- RAOIATION BE GREATER THAN ZERO
      IF(USE.GT.0.0) USE = 0.0
      CALSNOW = 1.17E-7 * ((USE + 273.16) ** 4)
C-----COMPUTE THE LONG WAVE RAOIATION COMPONENTS AS A FUNCTION OF THE
C----- FIRST, OETERMINE WHETHER THE SKIES ARE CLEAR OR CLOUOY
      IF(PRECIP) 30,30,40
C-----WITH CLEAR SKIES, THE OOWNWARO LONGWAVE RAOIATION COEFFICIENT IS
C----- .757 (RUNOFF FROM SNOWMELT, EM1110-2-1406, US ARMY CORPS OF
C----- ENGINEERS, 1960, PAGE 7)
   30 SNOSKY = (1.0 - COVOEN) * ((0.757 * CALAIR) - CALSNOW)
C-----THE OOWNWARD LONGWAVE RAOIATION COEFFICIENT IS 1.D BENEATH THE
C----- FOREST CANOPY (OR BENEATH CLOUOY SKIES)
      SNOCAN = COVOEN * (CALAIR - CALSNOW)
      RAOLWN = SNOCAN + SNOSKY
      GO TO 5D
C-----WITH CLOUOY SKIES, WHEN THE OOWNWARO LONGWAVE RAOIATION COEFFI-
C----- CIENT IS 1.0 INSTEAD OF .757, THE ABOVE THREE EQUATIONS MAY BE
C----- REOUCEO ALGEBRAICALLY TO THE FOLLOWING SINGLE EQUATION
   40 RAOLWN = CALAIR - CALSNOW
C-----COMPUTE THE CALORIC INPUT OR LOSS FROM THE NET EFFECT OF SHORT
C----- WAVE ANO LONG WAVE RAOIATION
   50 CALORIE = RAOSWN + RAOLWN
C-----THE SNOWPACK TEMPERATURE OIFFUSION MOOEL (LEAF, 1970, STUOY PLAN
C----- FS-RM-16D2, NO. 224.  ROCKY MOUNTAIN FOREST ANO RANGE EXP STA) IS
C----- INCORPORATEO TO CONTROL THE SNOWPACK TEMPERATURE ANO COLO CONTENT
C----- OURING NON-ISOTHERMAL CONOITIONS.  SEE NOW IF THE OIFFUSION MOOEL
C----- HAS BEEN INITIALIZEO.  IF SO, GO THROUGH THE LINKING ROUTINE
C----- WHICH INTERFACES THE DIFFUSION MOOEL WITH THE RAOIATION BALANCE
      IF(OREAOY) 60,70,60
   60 CALL LINK (IRETURN)
      IF(IRETURN) 7D,70,90
   70 IF(CALORIE) 8D,90,100
   80 CALL CALOSS (CALORIE)
   90 RETURN
  100 CALL CALIN (CALORIE)
      RETURN
      ENO
```

Subroutine RAINED

```
      SUBROUTINE RAINEO (TFORAIN,AMTRAIN)
C-----THIS SUBROUTINE COMPUTES THE EFFECT OF RAIN ON SNOW
C-----
```

```
C-----DICTIONARY
C     AMTRAIN - THE AMOUNT OF PRECIPITATION OCCURRING AS RAIN (INCHES)
C     CALRAIN - THE DEPLETION OF THE TOTAL CALORIE DEFICIT BY THIS RAIN
C               (CALORIES)
C     TFORAIN - THE TEMPERATURE FOR COMPUTING THE DEPLETION OF THE TOTAL
C               CALORIE DEFICIT CAUSED BY THIS RAIN (DEGREES C)
C-----
      COMMON ACTDATE,ACTUAL(21),AVETEMC,AVETEMF
      COMMON BASTEMF
      COMMON CALAIR,CALDEF,CALORIE,CALSNOW,COVDEN
      COMMON DATE,DATES(3),DEN,DENSITY,DREADY
      COMMON ENGBAL
      COMMON FOOTNOT(16),FREEWAT
      COMMON HOLDCAP
      COMMON IDATE(372),ISNOW,ITABLE
      COMMON KOUNT
      COMMON LASTUSD,LINES
      COMMON NEXTACT
      COMMON OBSWEQV
      COMMON PACKTEM,PARTICE,PASTINT,PLOTOBS,PLOTWE,PRECIP,PREWEQV
      COMMON RADIN,RADLWN,RADSWN,REFLECT
      COMMON SIMTEM1(3),SIMTEM2,SIMTEM3,SNOMELT,SOBSEQV(372),
     1       SPRECIP(372),SPREQV(372),SUBTITL(8)
      COMMON TCOEFF,TEMPMAX,TEMPMIN,THRSHLD,TITLE(8),TOTPREC
      COMMON USEMEAN
      COMMON XMAX
      INTEGER ACTDATE
      INTEGER DATE,DATES,DREADY
      INTEGER FOOTNOT
      INTEGER PASTINT,PLOTOBS,PLOTWE
      INTEGER SUBTITL
      INTEGER TITLE
      INTEGER USEMEAN
C-----ADD THIS AMOUNT OF PRECIPITATION TO THE PREDICTED WATER EQUIVALENT
      PREWEQV = PREWEQV + AMTRAIN
C-----SEE IF THERE IS A CALORIE DEFICIT IN THE PACK
      IF(CALDEF.LE.0.0) GO TO 50
C-----COMPUTE THE AMOUNT OF RAIN AT THIS TEMPERATURE THAT IS NEEDED TO
C----- WIPE OUT THE DEFICIT AND COMPARE IT WITH THE ACTUAL AMOUNT
      AMTNEED = CALDEF/((80.0 + TFORAIN) * 2.54)
      COMPARE = AMTRAIN - AMTNEED
      IF(COMPARE) 20,10,40
C-----THERE WAS JUST ENOUGH TO WIPE OUT THE DEFICIT
   10 CALDEF = 0.0
      PACKTEM = 0.0
      GO TO 30
C-----THERE WAS NOT ENOUGH TO WIPE IT OUT COMPLETELY.  JUST DEPLETE
C----- THE DEFICIT
   20 CALDEF = CALDEF - ((80.0 + TFORAIN) * AMTRAIN * 2.54)
      PACKTEM = -CALDEF/(PREWEQV*1.27)
C-----ADD ALL THE RAIN TO THE PACK AS ICE AND GET THE NEW HOLDING
C----- CAPACITY
   30 PARTICE = PARTICE + AMTRAIN
      HOLDCAP = 0.04 * PARTICE
      RETURN
C-----THERE WAS MORE THAN ENOUGH TO WIPE OUT THE DEFICIT.  ADD THE
C----- FROZEN PART TO THE ICE AND GET THE NEW HOLDING CAPACITY
   40 CALDEF = 0.0
      PACKTEM = 0.0
      PARTICE = PARTICE + AMTNEED
      HOLDCAP = 0.04 * PARTICE
C-----THE AMOUNT OF RAIN NOT FROZEN IS FREE WATER AND CONTRIBUTES
C----- CALORIC INPUT TO THE PACK
      FREEWAT = COMPARE
      CALL CALIN (TFORAIN * COMPARE * 2.54)
      RETURN
C-----ALL OF THE RAIN IS ADDED TO THE FREE WATER AND CONTRIBUTES CALORIC
C----- INPUT TO THE PACK
   50 FREEWAT = FREEWAT + AMTRAIN
      CALL CALIN (TFORAIN * AMTRAIN * 2.54)
      RETURN
      END
```

Subroutine RDPACK

```
      SUBROUTINE RDPACK
C-----THIS SUBROUTINE READS THE ACTUAL OR OBSERVED SNOWPACK TEMPERATURE
C----- CARD AND INITIALIZES THE DIFFUSION MODEL (SUBROUTINE DIFMOD).  IT
C----- IS CALLED WHENEVER COL 70 OF AN INPUT CARD IS NOT BLANK OR ZERO
      COMMON ACTDATE,ACTUAL(21),AVETEMC,AVETEMF
      COMMON BASTEMF
      COMMON CALAIR,CALDEF,CALORIE,CALSNOW,COVDEN
      COMMON DATE,DATES(3),DEN,DENSITY,DREADY
      COMMON ENGBAL
      COMMON FOOTNOT(16),FREEWAT
      COMMON HOLDCAP
      COMMON IDATE(372),ISNOW,ITABLE
      COMMON KOUNT
      COMMON LASTUSD,LINES
      COMMON NEXTACT
      COMMON OBSWEQV
      COMMON PACKTEM,PARTICE,PASTINT,PLOTOBS,PLOTWE,PRECIP,PREWEQV
      COMMON RADIN,RADLWN,RADSWN,REFLECT
      COMMON SIMTEM1(3),SIMTEM2,SIMTEM3,SNOMELT,SOBSEQV(372),
     1       SPRECIP(372),SPREQV(372),SUBTITL(8)
      COMMON TCOEFF,TEMPMAX,TEMPMIN,THRSHLD,TITLE(8),TOTPREC
      COMMON USEMEAN
      COMMON XMAX
      INTEGER ACTDATE
      INTEGER DATE,DATES,DREADY
      INTEGER FOOTNOT
      INTEGER PASTINT,PLOTOBS,PLOTWE
      INTEGER SUBTITL
      INTEGER TITLE
      INTEGER USEMEAN
      READ (5,910) I,ACTDATE,ACTUAL
  910 FORMAT(A10,1XI6,21F3.1)
C-----BE SURE THIS IS AN OBSERVED PACK TEMPERATURE CARD AND THAT THE
C----- DATE IS THE SAME AS THE CARD JUST READ BY SUBROUTINE READER.  IF
C----- NOT, ABORT THE JOB
      IF(I.EQ.10HOBS PACK T) GO TO 20
   10 PRINT 920,DATE,NEXTACT
  920 FORMAT(*1THE INPUT CARD DATED*I7,* INDICATED THAT AN OBSERVED PACK
     1 TEMPERATURE CARD WAS NEXT (COL 70 CONTAINED A*I2,*.* /*OBUT EITHE
     2R COLUMNS 1 - 10 OF THE NEXT CARD DO NOT CONTAIN -OBS PACK T- OR T
     3HE DATES ARE NOT THE SAME*)
      CALL SYSTEM (999,12H-JOB ABORTED)
   20 IF(DATE - ACTDATE) 10,30,10
C-----GET THE ACTUAL AVERAGE SNOWPACK TEMPERATURE (THE TEMPERATURES READ
C----- IN ARE ALL POSITIVE - THE NEGATIVES WILL BE INSERTED BY THIS
C----- SUBROUTINE)
   30 DUMMY1 = 1.0
      DUMMY2 = ACTUAL(20)
      DO 60 I = 1,19
C-----WATCH FOR BLANKS TO PREVENT AVERAGING ZEROES (A BLANK IS READ AS A
C----- NEGATIVE ZERO, WHICH MAY BE DETECTED BY THE FOLLOWING TWO TESTS)
      IF(ACTUAL(I)) 50,40,50
   40 IF(SIGN(1.0,ACTUAL(I))) 70,70,50
   50 DUMMY1 = DUMMY1 + 1.0
   60 DUMMY2 = DUMMY2 + ACTUAL(I)
C-----COMPUTE THE AVERAGE
   70 SIMTEM3 = - DUMMY2/DUMMY1
C-----FILL IN -SIMTEM1- WITH THE OBSERVED TEMPERATURES.  START WITH THE
C----- AVERAGE AIR TEMPERATURE
      SIMTEM1(1) = AMIN1 (AVETEMC,0.0)
C-----GROUND TEMPERATURE
      SIMTEM1(3) = - ACTUAL(20)
C-----FIND THE MEDIAN DEPTH OF THE PACK FROM THE WATER EQUIVALENT
      WEQV = PREWEQV + PRECIP
C-----IF THE DENSITY WAS NOT SPECIFIED ON THE INPUT CARD, COMPUTE IT AS
C----- A FUNCTION OF THE WATER EQUIVALENT.  (THE FUNCTION WAS DERIVED
C----- FROM 1969 OBSERVED CONDITIONS ON THE FRASER EXPERIMENTAL FOREST)
      IF(DEN) 90,90,80
   80 DENSITY = DEN
      GO TO 100
   90 DENSITY = (EXP((0.0179 * WEQV) + 3.02))/100.0
C-----DEPTH = WEQV/DENSITY
C-----MEDIAN = DEPTH/2
  100 DUMMY1 = WEQV/(DENSITY + DENSITY)
C-----INTERPOLATE BETWEEN THE ACTUAL TEMPERATURES ON EITHER SIDE OF THIS
C----- DEPTH TO OBTAIN THE TEMPERATURE.  (THE SUBSCRIPT OF THE TEMP
C----- ABOVE IT IS FOUND BY TRUNCATING THE QUOTIENT OF THIS DEPTH
C----- DIVIDED BY THE DISTANCE BETWEEN MEASUREMENTS.  THE INTERPOLATION
C----- IS LINEAR)
      SUBSCRP = DUMMY1/ACTUAL(21)
      I = SUBSCRP
      TRUNCAT = I
      SIMTEM1(2) = - ACTUAL(I) - ((ACTUAL(I) - ACTUAL(I+1)) * (TRUNCAT -
     1 SUBSCRP))
C-----INDICATE THAT THE DIFFUSION MODEL HAS BEEN INITIALIZED AND IS
C----- READY FOR USE
      DREADY = 1
      RETURN
      END
```

Subroutine READER

```
      SUBROUTINE READER (IEND)
C-----THIS SUBROUTINE READS A DATA CARD AND COMPUTES THE AVERAGE
C----- TEMPERATURES
      COMMON ACTDATE,ACTUAL(21),AVETEMC,AVETEMF
      COMMON BASTEMF
      COMMON CALAIR,CALDEF,CALORIE,CALSNOW,COVDEN
      COMMON DATE,DATES(3),DEN,DENSITY,DREADY
      COMMON ENGBAL
      COMMON FOOTNOT(16),FREEWAT
      COMMON HOLDCAP
      COMMON IDATE(372),ISNOW,ITABLE
      COMMON KOUNT
      COMMON LASTUSD,LINES
      COMMON NEXTACT
      COMMON OBSWEQV
      COMMON PACKTEM,PARTICE,PASTINT,PLOTOBS,PLOTWE,PRECIP,PREWEQV
      COMMON RADIN,RADLWN,RADSWN,REFLECT
      COMMON SIMTEM1(3),SIMTEM2,SIMTEM3,SNOMELT,SOBSEQV(372),
     1       SPRECIP(372),SPREQV(372),SUBTITL(8)
      COMMON TCOEFF,TEMPMAX,TEMPMIN,THRSHLD,TITLE(8),TOTPREC
      COMMON USEMEAN
      COMMON XMAX
      INTEGER ACTDATE
      INTEGER DATE,DATES,DREADY
      INTEGER FOOTNOT
      INTEGER PASTINT,PLOTOBS,PLOTWE
      INTEGER SUBTITL
      INTEGER TITLE
      INTEGER USEMEAN
      COMMON/CONVERT/FIVE9TH,THIRTY2
C-----READ A CARD AND CHECK FOR THE END OF FILE
      READ (5,900) DATES,RADIN,TEMPMAX.TEMPMIN,OBSWEQV,PRECIP,DEN,
     1 NEXTACT
  900 FORMAT(3I2,F4.0,7X,2F4.1,14X3F5.2,15XI1)
      IF(EOF(5)) 20,20,10
   10 IEND = 1
      RETURN
   20 IEND = 0
      DATE = DATES(1)*10000 + DATES(2)*100 + DATES(3)
      IF(DATE) 70,70,30
C-----COMPUTE THE MEAN TEMPERATURE IN FARENHEIT, THEN CONVERT IT TO
```

```
C----- CENTIGRAOE
   30 AVETEMF = (TEMPMAX + TEMPMIN) * 0.5
      AVETEMC = (AVETEMF - THIRTY2) * FIVE9TH
      IF(USEMEAN) 50,50,40
   40 TEMPMAX = AVETEMF
      TEMPMIN = AVETEMF
C-----SEE IF THE NEXT CARO IS AN ACTUAL PACK TEMPERATURE CARO
   50 IF(NEXTACT) 70,70,60
   60 CALL ROPACK
   70 RETURN
      ENO
```

Subroutine SNOWED

```
      SUBROUTINE SNOWEO (TFORSNO,AMTSNOW)
C-----THIS SUBROUTINE COMPUTES THE EFFECTS OF A SNOW EVENT ON THE
C----- SNOWPACK
C-----
C-----OICTIONARY
C-----
C      AMTSNOW - THE AMOUNT OF PRECIPITATION OCCURRING AS SNOW (INCHES)
C      CALSNOW - THE CONTRIBUTION OF THIS SNOW TO THE TOTAL CALORIE
C                OEFICIT (CALORIES)
C      TFORSNO - THE TEMPERATURE FOR COMPUTING THE CONTRIBUTION OF THIS
C                SNOW TO THE TOTAL CALORIE OEFICIT (OEGREES C)
C-----
      COMMON ACTOATE,ACTUAL(21),AVETEMC,AVETEMF
      COMMON BASTEMF
      COMMON CALAIR,CALOEF,CALORIE,CALSNOW,COVOEN
      COMMON OATE,OATES(3),OEN,OENSITY,OREAOY
      COMMON ENGBAL
      COMMON FOOTNOT(16),FREEWAT
      COMMON HOLOCAP
      COMMON IOATE(372),ISNOW,ITABLE
      COMMON KOUNT
      COMMON LASTUSO,LINES
      COMMON NEXTACT
      COMMON OBSWEQV
      COMMON PACKTEM,PARTICE,PASTINT,PLOTOBS,PLOTWE,PRECIP,PREWEQV
      COMMON RAOIN,RAOLWN,RAOSWN,REFLECT
      COMMON SIMTEM1(3),SIMTEM2,SIMTEM3,SNOMELT,SOBSEQV(372),
     1       SPRECIP(372),SPREQV(372),SUBTITL(B)
      COMMON TCOEFF,TEMPMAX,TEMPMIN,THRSHLO,TITLE(B),TOTPREC
      COMMON USEMEAN
      COMMON XMAX
      INTEGER ACTOATE
      INTEGER OATE,OATES,OREAOY
      INTEGER FOOTNOT
      INTEGER PASTINT,PLOTOBS,PLOTWE
      INTEGER SUBTITL
      INTEGER TITLE
      INTEGER USEMEAN
      ISNOW = 1
C-----AOO THIS AMOUNT OF PRECIPITATION TO THE PREOICTEO WATER EQUIVALENT
C----- ANO GET THE NEW HOLOING CAPACITY
      PREWEQV = PREWEQV + AMTSNOW
      PARTICE = PARTICE + AMTSNOW
      HOLOCAP = 0.04 * PARTICE
C-----THE SNOW FALLING WHEN THE TEMPERATURE IS BETWEEN 35 ANO 32 OEGREES
C----- OOES NOT ALTER THE CALORIC OEFICIT
      IF(TFORSNO.GE.0.0) RETURN
C-----COMPUTE THE CALORIE OEFICIT FOR THIS SNOW BY THE EQUATION
C----- CALORIE OEFICIT = S(I)*OELTA T*P, WHERE
C----- S(I) = SPECIFIC HEAT OF ICE (.5 CAL/CM/OEGREES C),
C----- OELTA T = CHANGE IN TEMPERATURE WITH RESPECT TO FREEZING (0.0
C-----  OEGREES CENTIGRAOE), ANO
C----- P = PRECIPITATION IN CM (CONVERSION FACTOR = 2.54 CM/IN).
C----- THEREFORE, CALORIE OEFICIT = 0.5 * (TFORSNO) * (AMTSNOW * 2.54)
      CALL CALOSS (TFORSNO * AMTSNOW * 1.27)
      RETURN
      ENO
```

Subroutine STORE

```
      SUBROUTINE STORE
C-----STORE THE INFORMATION NEEOEO FOR THE PLOT
      COMMON ACTOATE,ACTUAL(21),AVETEMC,AVETEMF
      COMMON BASTEMF
      COMMON CALAIR,CALDEF,CALORIE,CALSNOW,COVOEN
      COMMON OATE,OATES(3),OEN,OENSITY,OREAOY
      COMMON ENGBAL
      COMMON FOOTNOT(16),FREEWAT
      COMMON HOLOCAP
      COMMON IOATE(372),ISNOW,ITABLE
      COMMON KOUNT
      COMMON LASTUSO,LINES
      COMMON NEXTACT
      COMMON OBSWEQV
      COMMON PACKTEM,PARTICE,PASTINT,PLOTOBS,PLOTWE,PRECIP,PREWEQV
      COMMON RAOIN,RAOLWN,RAOSWN,REFLECT
      COMMON SIMTEM1(3),SIMTEM2,SIMTEM3,SNOMELT,SOBSEQV(372),
     1       SPRECIP(372),SPREQV(372),SUBTITL(B)
      COMMON TCOEFF,TEMPMAX,TEMPMIN,THRSHLO,TITLE(B),TOTPREC
      COMMON USEMEAN
      COMMON XMAX
      INTEGER ACTOATE
      INTEGER OATE,OATES,OREAOY
      INTEGER FOOTNOT
      INTEGER PASTINT,PLOTOBS,PLOTWE
      INTEGER SUBTITL
      INTEGER TITLE
      INTEGER USEMEAN
C-----KEEP TRACK OF THE LARGEST VALUE FOR SCALING THE PLOT
      XMAX = AMAX1 (XMAX,OBSWEQV,PREWEQV)
C-----INCREASE THE COUNTER
      KOUNT = KOUNT + 1
      IDATE(KOUNT) = OATE
      SPRECIP(KOUNT) = PRECIP
      SPREQV(KOUNT) = PREWEQV
      IF(PLOTOBS) 10,10,20
C-----BY STORING A NUMBER OUTSIOE THE LIMITS OF THE PLOT, IT WILL BE
C----- IGNOREO
   10 SOBSEQV(KOUNT) = -1.0
      RETURN
C-----THE OBSERVEO WATER EQUIVALENT IS TO BE PLOTTEO
   20 SOBSEQV(KOUNT) = OBSWEQV
      RETURN
      ENO
```

Subroutine TSPLOT

```
      SUBROUTINE TSPLOT(MX,X1,X2,X3,X4,X5,X6,XMAX,XMIN,IT,INT,INIT)
C-----THIS ROUTINE OOES THE ACTUAL PLOTTING
C. HWANG, A.C. HOGGATT   1 JULY, 1962
C     ARGUMENTS
C    MX=NUMBER OF VARIABLES TO BE PLOTTEO, LESS THAN OR EQUAL TO 6
C    X1=VALUE ATTACHEO TO FIRST VARIABLE. PLOTTING SYMBOL WILL BE A 1.
C    X2=VALUE ATTCHEO TO SECONO VARIABLE. PLOTTING SYMBOL WILL BE A 2.
C    X3
C    .
C    .
C    X6 ANO SO ON FOR XN
C    XMAX=UPPER ENO OF OROINATE SCALE
C    XMIN=LOWER ENO OF OROINATE SCALE
C    IT =ABCISSA VALUE. (I.E., T, FOR XT)
C    INT=ABCISSA LABELLING INTERVAL. (I.E., EVERY ICHTH LINE OF PLOT
C    WILL BE LABELLEO WITH VALUE OF IOY ON HORIZONTAL AXIS)
C    INIT  =INITIALIZING PARAMETER, USEO AS FOLLOWS.
C               INIT   =1, GRAPH WILL COMPUTE ANO PR9NT OROINATE, PLOO
C    ANO PRINT FIRST LINE OF GRAPH. SUBSEQUENT CALL WILL PLOT ANO PR+NT
C    A LINE OF GRAPH ONLY.
C            INIT  =-1 USEO TO REAOY SUBROUTINE FOR PLOTTING NEW GRAPH.
C    SUBROUTINE OOES NO PLOTTING OR PRINTING WITH THIS SETTING OF INIT.
C        IF THE VALUE OF SCALING PARAMETERS XMIN ANO/OR XMAX OIFFER FROM
C        THE PREVIOUSLY GIVEN ONES WITHOUT RESETTING OF INIT,    TS PLOT
C        WILL RESET SCALE ACCOROING TO NEW XMIN ANO/OR XMAX ANO PRINT OUT
C        NEW OROINATE POINT VALUES TO AGREE WITH SCALING OF PLOTTEO POINTS
C     INTERNAL VARIABLES
C    CHARS CONTAINS BCO CHARACTERS USEO AS PLOTTING SYMBOL.
C    PLOT HOLOS THE HOLLERITH IMAGE FOR ONE LINE OF PLOT.
C    XN. SCALAR ARGUMENTS ARE STOREO IN THIS LINEAR ARRAY.
C    OELTA IS A SCALING PARAMETER, EQUAL TO THE RANGE DIVIOEO BY 110, ANO
C        IS RECOMPUTEO WHEN NEW SCALE IS INOICATEO (WHEN INIT  =1 OR WHEN
C        XMAX OR XMIN VALUE OIFFERING FROM PREVIOUS VALUE IS GIVEN).
C    PASMIN, PASMAX, ARE FOR REMEMBERING PREVIOUS VALUE OF XMIN, XMAX.
      OIMENSION CHARS(B), PLOT(111), OROPT(6), XN(6)
      EQUIVALENCE(OROPT(6),PLOT(6))
      OATA  CHARS(1)/1H1/, CHARS(2)/1H2/, CHARS(3)/1H3/, CHARS(4)/1H4/,
     *CHARS(5)/1H5/, CHARS(6)/1H6/, CHARS(7)/1H /, CHARS(B)/1H./
      OATA NCALLS/O/,NOY/O/
      IF(INIT)1000,1000,9001
CALL WAS TO INITIALIZE ONLY....
 1000 NOY=0
      NCALLS=0
      GO TO 701
COMMENCE BY PROTECTING THE INOEX MX
 9001 M=MAXO(MX,1)
      M=MINO(M,6)
CONJURE PLOTTING CHARACTERS
    3 XN(1)=X1
      XN(2)=X2
      XN(3)=X3
      XN(4)=X4
      XN(5)=X5
      XN(6)=X6
      IF(NOY) 15,15,28
   28 IF(PASMAX-XMAX) 45,40,45
   40 IF(PASMIN-XMIN) 45,80,45
   15 NOY=1
COMPUTE ANO PRINT OROINATE POINTS, SCALE.
   45 AN=(XMAX-XMIN)*.2
      OROPT(1)=XMIN
      NCALLS = 0
      OO 17 I=2,6
   17 OROPT(I)=OROPT(I-1)+AN
      WRITE (6,100) (OROPT(N),N=1,6)
      OO 705 N=1,2
      WRITE (6,101)
  705 CONTINUE
  101 FORMAT(     9X1H.,5(21X1H.))
      WRITE (6,800)
  800 FORMAT(     9X111(1H.))
  100 FORMAT(1H1,4(E10.3,12X),E10.3,11X,E10.3)
      OELTA=(XMAX-XMIN)/110.
CLEAR PRINTER LINE.
   80 OO 99 K=2,111
        PLOT(K)=CHARS(7)
   99 CONTINUE
      PLOT(1)=CHARS(B)
CAUSE X TO BE PUT ON THE INTERVAL (1,111).
   20 OO 34 N=1,M
        LOC=1.5+(XN(N)-XMIN)/OELTA
CHECK FOR X WITHIN THE INTERVAL (XMIN,XMAX),
      IF(LOC) 34,34,B11
  B11 IF(111-LOC) 34,B14,B14
CHARACTERS FOR PRINTING NOW GET OROPPEO INTO PLACE.
  B14 PLOT(LOC)=CHARS(N)
```

```
   34 CONTINUE
CHOOSE OUTPUT FORMAT.
      NCALLS=NCALLS+I
      IF(MOD(NCALLS,INT)) B15,2004,B15
CRANK OUT ONE LINE OF PLOT.
 2004 WRITE (6,700) IT,(PLOT(K),K=1,III)
      GO TO 702
  700 FORMAT(1H    I6,2H..1IIA1)
  B15 WRITE (6,600) (PLOT(K),K=I,11I)
  600 FORMAT(9H           111AI)
702   PASMAX=XMAX
      PASMIN=XMIN
CODING COMPLETED.
  701 RETURN
      END
```

Subroutine WRITER

```
      SUBROUTINE WRITER (CODE)
C-----THIS SUBROUTINE KEEPS TRACK OF THE PRINTING DETAILS
      COMMON ACTDATE,ACTUAL(21),AVETEMC,AVETEMF
      COMMON BASTEMF
      COMMON CALAIR,CALOEF,CALORIE,CALSNOW,COVDEN
      COMMON DATE,DATES(3),DEN,DENSITY,DREADY
      COMMON ENGBAL
      COMMON FOOTNOT(I6),FREEWAT
      COMMON HOLDCAP
      COMMON IDATE(372),ISNOW,ITABLE
      COMMON KOUNT
      COMMON LASTUSD,LINES
      COMMON NEXTACT
      COMMON OBSWEQV
      COMMON PACKTEM,PARTICE,PASTINT,PLOTOBS,PLOTWE,PRECIP,PREWEQV
      COMMON RADIN,RADLWN,RADSWN,REFLECT
      COMMON SIMTEMI(3),SIMTEM2,SIMTEM3,SNOMELT,SOBSEQV(372),
     I       SPRECIP(372),SPREQV(372),SUBTITL(B)
      COMMON TCOEFF,TEMPMAX,TEMPMIN,THRSHLD,TITLE(8),TOTPREC
      COMMON USEMEAN
      COMMON XMAX
      INTEGER ACTDATE
      INTEGER DATE,DATES,DREADY
      INTEGER FOOTNOT
      INTEGER PASTINT,PLOTOBS,PLOTWE
      INTEGER SUBTITL
      INTEGER TITLE
      INTEGER USEMEAN
C-----CHECK THE LINE COUNTER
      IF(LINES - 48) 40,IO,IO
C-----SEE IF THIS IS STARTING A NEW STATION - IF SO, BYPASS THE FOOTNOTE
   IO IF(LINES - 999) 20,30,30
C-----WRITE THE FOOTNOTE
   20 WRITE (6,910) FOOTNOT
  910 FORMAT(IH013AIO/IX3AIO)
C-----HEADINGS
   30 WRITE (6,920) TITLE,SUBTITL
  920 FORMAT(1HI50X*SNOWMELT RUNOFF SIMULATION MODEL*/27X8AIO/27X8AIO)
      WRITE (6,930) TCOEFF,COVDEN
  930 FORMAT(* TRANSMISIVITY COEFFICIENT =*F4.2,74X*COVER DENSITY =*F7.2
     I)
      WRITE (6,940)
  940 FORMAT(*0*32X*TEMPERATURE (F)   PRECIP (IN)       NET RAD (CAL)
     1ENERGY     SNOWPACK  PREDICTED*/
     223X*DATE        MAX    MIN    AVE      DAY   ACCUM         SHORT      LONG  B
     3AL (CAL)  TEMP (C)  W.E. (IN)*/)
      LINES = 0
   40 WRITE (6,950) DATES,TEMPMAX,TEMPMIN,AVETEMF,PRECIP,TOTPREC,RADSWN,
     I RADLWN,ENGBAL,PACKTEM,PREWEQV
  950 FORMAT(IH020XI2,2I3,IX3F6.I,2F7.2,3X3FB.I,6XF5.I,5XF6.2)
      LINES = LINES + 2
      RETURN
      END
```

Sample Input

```
111      35    40 -450   634 6000

         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

                     FRASER EXPERIMENTAL FOREST, COLORADO
                      OEADHORSE CREEK, LOWER SOUTH SLOPE
ELEVATION 9800 FT.
                                                      ASPECT SSE, SLOPE 30 PERCENT
  12569 171        310  90                -0   61                    1
085 PACK T 012569 45 45 45 45 45 45 45 45 45 45                                 10 60
  12669 180        400 190                -0    5
  12769 189        360 170                -0   39
  12869 198        280  30                -0    4
  12969 207        230 -80                -0    3
  13069 417        210-180                -0    0
  13169 423        200-140                -0    0
  20169 234        190-160                -0    9
  20269 243         60-110                -0   13
  20369 441        220-230                -0    0
  20469 447        360-170                -0    0
  20569 453        350 -60                -0    0
  20669 279        300  10                -0    6
  20769 465        250  50                -0    0
  20869 468        290 -90                -0    0
  20969 471        370-120                -0    0
  21069 294        370 -80                -0    2
  21169 478        410  20                -0    0
  21269 481        390  30                -0    0
  21369 300        410  50                -0    6
  21469 488        360 160                -0    0
  21569 304        370 -40                -0    5
  21669 306        360 120                -0   21
  21769 308        310 -40                -0    3
  21869 501        400-110                -0    0
  21969 312        430  10                -0   27
  22069 314        250 120                -0   26
  22169 310        270 -10                -0    9
  22269 509        310 -90                -0    0
  22369 510        330 -90                -0    0
  22469 510        360 -10                -0    0
  22569 511        440  30                -0    0
  22669 291        470  60                -0   13
  22769 513        260 -70                -0    0
  22869 514        420 -80                -0    0
  30169 279        410 -90                -0   18                    1
085 PACK T 030169 31 31 31 31 31 31 31                                          10 60
  30269 275        380 -90                -0    2
  30369 516        370 -90                -0    0
  30469 517        380  20                -0    0
  30569 264        240 -90                -0   10
  30669 260        320 -80                -0   16
  30769 519        200 -90                -0    0
  30869 522        200-190                -0    0
  30969 525        210-100                -0    0
  31069 528        330-210                -0    0
  31169 530        280-130                -0    0
  31269 263        270-200                -0    3
  31369 536        210-140                -0    0
  31469 539        370-200                -0    0
  31569 541        420-170                -0    0
  31669 544        480-150                -0    0
  31769 547        490  20                -0    0
  31869 550        470 120                -0    0
  31969 272        290 130                -0   31
  32069 555        400 -80                -0    0
  32169 558        500 -40                -0    0
  32269 567        490 140                -0    0
  32369 300        290  60                -0    3
  32469 312        290  70                -0    2
  32569 325        190  50                -0    6
  32669 601        360  50                -0    0
  32769 610        550 130                -0    0
  32869 619        550 250                -0    0
  32969 628        550 240                -0    0
  33069 636        600 270                -0    0
  33169 562        630 320                -0    0
  40169 196        340 300              1060   36                    1
085 PACK T 040169 01 01 01 01 01 01                                             00 60
  40269 562        560 220                -0    0
  40369 559        580 300                -0    9
  40469 526        440 260                -0    0
  40569 685        600 260                -0    0
  40669 631        580 330                -0    0
  40769 481        380 180                -0    9
  40869 354        480 190                -0    0
  40969 669        500 180               760    0
  41069 645        510 260                -0    0
  41169 481        520 280                -0    0
  41269 156        370 290                -0   23
  41369 481        370 270                -0    0
  41469 515        450 260                -0    0
  41569 384        480 170               930   60
  41669 180        440 190                -0    9
  41769 601        450 200                -0    0
  41869 540        510 210                -0    0
  41969 718        540 260                -0    0
  42069 722        570 210                -0    0
  42169 704        630 310                -0    0
  42269 576        600 360               510    0
  42369 612        620 250                -0   41
  42469 725        620 300                -0    0
  42569 562        330 150                -0    0
  42669 466        320 130                -0   11
  42769 618        360 140                -0    0
  42869 673        540 170                -0    0
  42969 633        520 290               200    0
  43069 706        530 300                -0    0
  50169 629        610 300                -0    0
  50269 711        680 330                -0    6
  50369 578        630 320                -0    0
  50469 551        460 320                -0    0
  50569 259        450 320                -0    6
  50669 546        380 320                -0  120
  50769 304        360 320                -0   64
  50869 600        500 180                -0    0
  50969 812        600 220                -0    0
  51069 789        590 300                -0    0
  51169 735        630 340                -0    0
  51269 635        580 340                -0    0
  51369 578        620 360                -0    0
  51469 586        610 320                -0    0
  51569 419        460 320                -0   13
  51669 388        390 310                -0   76
  51769 766        620 300                -0    0
  51869 689        610 380                -0    0
  51969 504        700 390                -0    0
  52069 738        700 420                -0    0
  52169 658        680 360                -0   12
  52269 567        650 340                -0   10
  52369 530        640 370                -0    9
  52469 711        630 350                -0    0
  52569 718        760 400                -0    0
  52669 802        790 440                -0    0
  52769 618        810 480                -0    0
  52869 686        760 420                -0    0
  52969 646        750 400                -0    0
  53069 726        740 420                -0    6
  53169 667        410 300                -0    4
  60169 691        500 240                      6
  60269 653        620 260                     -0
  60369 643        570 340                     -0
  60469 691        680 390                     -0
  60569 614        730 460                      4
  60669 384        640 360                     19
  60769 346        500 360                     44
  60869 595        660 360                     10
  60969 634        670 360                     -0
  61069 566        670 340                      5
  61169 288        400 320                     55
  61269 403        460 320                     36
  61369 490        470 310                     22
  61469 403        470 320                     14
  61569 307        450 340                     52
  61669 480        500 340                     19
  61769 221        460 370                     54
  61869 422        490 370                      2
  61969 595        600 350                     -0
```

```
  62069 634          640 340                            -0
  62169 662          650 310                            -0
  62269 480          530 370                            -0
  62369 365          520 420                            17
  62469 394          520 350                            76
  62569 374          390 330                            21
  62669 451          380 320                            39
  62769 806          640 310                            -0
  62869 816          720 330                            -0
  62969 826          690 320                            -0
  63069 758          690 310                            -0


         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

111      25    55 -480   843 3200
                          FRASER EXPERIMENTAL FOREST, COLORADO
                           DEADHORSE CREEK, UPPER NORTH SLOPE
ELEVATION 10500 FT.
                                                     ASPECT NE, SLOPE 35 PERCENT
 12569  59           200 110                    -0   77                     1      009
OBS PACK T 012569 48 48 48 48 48 48 48 48 48 48                                  10 60
 12669  63           290 210                    -0    6                            009
 12769  67           250 190                    -0   49                            009
 12869  71           170  50                    -0    5                            009
 12969  75           120 -60                    -0    4                            009
 13069 149           100-160                    -0    0                            009
 13169 153            90-120                    -0    0                            009
 20169  88            80-140                    -0   11                            009
 20269  92           -50 -90                    -0   16                            009
 20369 165           110-210                    -0    0                            009
 20469 169           250-150                    -0    0                            009
 20569 173           240 -40                    -0    0                            009
 20669 108           190  30                    -0    8                            009
 20769 181           140  70                    -0    0                            009
 20869 185           180 -70                    -0    0                            009
 20969 189           260-100                    -0    0                            009
 21069 120           260 -60                    -0    3                            009
 21169 198           300  40                    -0    0                            009
 21269 202           280  50                    -0    0                            009
 21369 128           300  70                    -0    8                            009
 21469 210           250 180                    -0    0                            009
 21569 133           260 -20                    -0    6                            009
 21669 136           250 140                    -0   27                            009
 21769 138           200 -20                    -0    4                            009
 21869 227           290 -90                    -0    0                            009
 21969 143           320  30                    -0   34                            009
 22069 146           140 140                    -0   33                            009
 22169 146           160  10                    -0   11                            009
 22269 242           200 -70                    -0    0                            009
 22369 245           220 -70                    -0    0                            009
 22469 249           250  10                    -0    0                            009
 22569 252           330  50                    -0    0                            009
 22669 144           360  80                    -0   16                            009
 22769 258           150 -50                    -0    0                            009
 22869 262           310 -60                    -0    0                            009
 30169 142           300 -70                    -0   23                     1      009
OBS PACK T 030169 35 35 35 35 35 35 35 35                                        10 60
 30269 142           270 -70                    -0    3                            009
 30369 271           260 -70                    -0    0                            009
 30469 274           270  40                    -0    0                            009
 30569 141           130 -70                    -0   13                            009
 30669 140           210 -60                    -0   20                            009
 30769 284            90 -70                    -0    0                            009
 30869 289            90-170                    -0    0                            009
 30969 294           100 -80                    -0    0                            009
 31069 299           220-190                    -0    0                            009
 31169 303           170-110                    -0    0                            009
 31269 152           160-180                    -0    4                            009
 31369 313           100-120                    -0    0                            009
 31469 318           260-180                    -0    0                            009
 31569 323           310-150                    -0    0                            009
 31669 328           370-130                    -0    0                            009
 31769 332           380  40                    -0    0                            009
 31869 337           360 140                    -0    0                            009
 31969 169           180 150                    -0   39                            009
 32069 347           290 -60                    -0    0                            009
 32169 352           390 -20                    -0    0                            009
 32269 361           380 160                    -0    0                            009
 32369 194           180  80                    -0    4                            009
 32469 205           180  90                    -0    3                            009
 32569 215            80  70                    -0    8                            009
 32669 399           250  70                    -0    0                            009
 32769 408           250  80                    -0    0                            009
 32869 418           320 180                    -0    0                            009
 32969 427           330 170                    -0    0                            009
 33069 437           370 220                    -0    0                            009
 33169 429           430 270                    -0    0                            009
 40169 150           310 200                  1340   45  .28                1      009
OBS PACK T 040169 21 24 27 29 30 30 27 16                                        10 60
```

```
 40269 429           390 180                    -0    0                            009
 40369 470           410 220                    -0   11                            009
 40469 402           340 220                    -0    0                            009
 40569 523           380 220                    -0    0                            009
 40669 482           450 290                    -0    0                            009
 40769 367           300 120                    -0   11                            009
 40869 270           320 130                    -0    0                            009
 40969 511           360 180                  1350    0  .32                1      009
OBS PACK T 040969 34 33 38 23 21 19 17                                           10 60
 41069 492           400 230                    -0    0                            009
 41169 367           450 270                    -0    0                            009
 41269 119           340 250                    -0   29                            009
 41369 367           330 230                    -0    0                            009
 41469 393           360 220                    -0    0                            009
 41569 293           400 200                  1410   76  .30                1      009
OBS PACK T 041569 18 18 16 14 13 12 12 11                                        10 60
 41669 138           280 150                    -0   11                            009
 41769 459           320 150                    -0    0                            009
 41869 412           400 160                    -0    0                            009
 41969 549           440 220                    -0    0                            009
 42069 551           470 170                    -0    0                            009
 42169 538           530 300                    -0    0                            009
 42269 440           450 330                  1290    0  .28                1      009
OBS PACK T 042269 01 02 02 04 05 04 04                                           04 60
 42369 467           550 320                    -0   52                            009
 42469 554           520 240                    -0    0                            009
 42569 429           240  90                    -0    0                            009
 42669 356           200  80                    -0   14                            009
 42769 472           270  80                    -0    0                            009
 42869 514           380 150                    -0    0                            009
 42969 483           420 220                  1230    0                            009
 43069 539           470 260                    -0    0                            009
 50169 480           520 280                    -0    0                            009
 50269 543           550 300                    -0    8                            009
 50369 441           510 280                    -0    0                            009
 50469 466           410 300                    -0    0                            009
 50569 219           350 280                    -0    8                            009
 50669 461           320 280                  1170  152                            009
 50769 257           300 240                    -0   81                            009
 50869 507           380 220                    -0    0                            009
 50969 686           420 260                    -0    0                            009
 51069 667           520 300                    -0    0                            009
 51169 621           480 300                    -0    0                            009
 51269 537           490 320                    -0    0                            009
 51369 488           540 300                  1200    0                            009
 51469 496           470 300                    -0    0                            009
 51569 354           440 280                    -0   16                            009
 51669 328           350 260                    -0   96                            009
 51769 647           510 250                    -0    0                            009
 51869 582           500 340                    -0    0                            009
 51969 426           550 340                    -0    0                            009
 52069 624           580 360                  1210    0                            009
 52169 556           530 310                    -0   15                            009
 52269 479           540 310                    -0   13                            009
 52369 448           540 320                    -0   11                            009
 52469 601           540 320                    -0    0                            009
 52569 607           590 370                    -0    0                            009
 52669 678           630 390                    -0    0                            009
 52769 523           670 420                   760    0                            009
 52869 580           660 380                    -0    0                            009
 52969 546           600 390                    -0    0                            009
 53069 614           600 330                    -0    8                            009
 53169 564           430 260                    -0    5                            009
 60169 670           400 220                    -0    6                            009
 60269 632           480 260                    -0   -0                            009
 60369 623           510 320                   380   -0                            009
 60469 670           610 370                    -0   -0                            009
 60569 595           670 440                    -0    4                            009
 60669 372           580 340                    -0   19                            009
 60769 335           440 340                    -0   44                            009
 60869 577           600 340                    -0   10                            009
 60969 614           610 340                    -0   -0                            009
 61069 549           610 320                    -0    5                            009
 61169 279           340 300                    -0   55                            009
 61269 391           400 300                    -0   36                            009
 61369 474           410 290                    -0   22                            009
 61469 391           410 300                    -0   14                            009
 61569 298           390 320                    -0   52                            009
 61669 465           440 320                    -0   19                            009
 61769 214           400 350                    -0   54                            009
 61869 409           430 350                    -0    2                            009
 61969 577           540 330                    -0   -0                            009
 62069 614           580 320                    -0   -0                            009
 62169 642           590 290                    -0   -0                            009
 62269 465           470 350                    -0   -0                            009
 62369 353           460 400                    -0   17                            009
 62469 381           460 330                    -0   76                            009
 62569 363           330 310                    -0   21                            009
 62669 437           320 300                    -0   39                            009
 62769 781           580 290                    -0   -0                            009
 62869 790           660 310                    -0   -0                            009
 62969 800           630 300                    -0   -0                            009
 63069 735           630 290                    -0   -0                            009
```

Leaf, Charles F., and Glen E. Brink.
1973. Computer simulation of snowmelt within a Colorado subalpine watershed. USDA For. Serv. Res. Pap. RM-99, **22** p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

A dynamic model which simulates snowmelt in Colorado subalpine watersheds for all combinations of aspect, slope, elevation, and forest cover composition and density is described. The model simulates winter snow accumulation, the energy balance, snowpack condition, and resultant melt in time and space. Detailed flow chart descriptions of the various components of the model and a program listing are presented.

Keywords: Computer models, coniferous forests, model studies, simulation analysis, snowmelt, watershed management.

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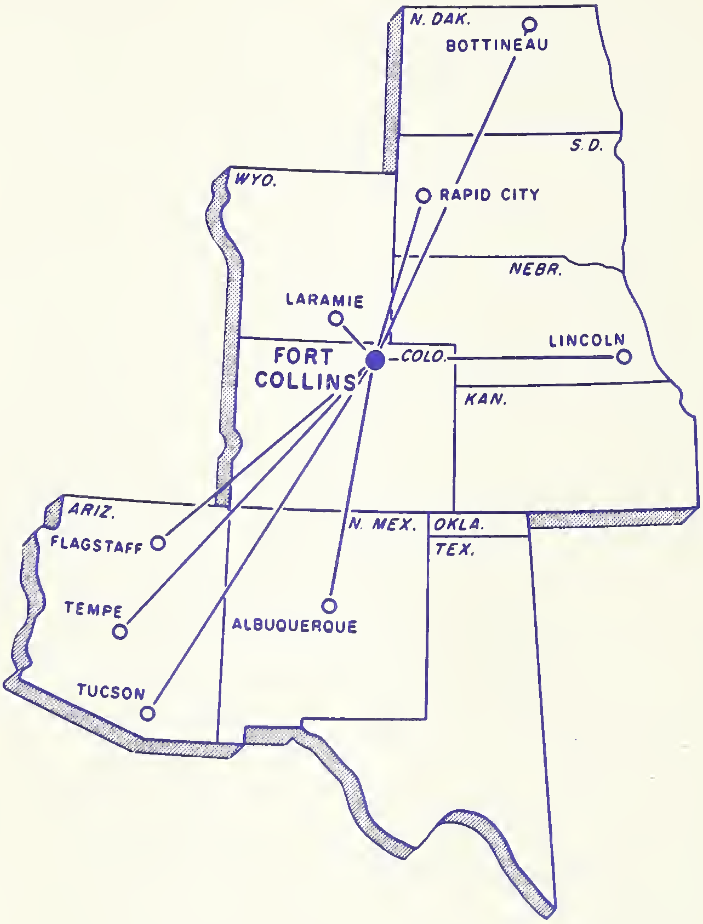
N. DAK.
BOTTINEAU
S.D.
WYO.
RAPID CITY
NEBR.
LARAMIE
FORT COLLINS
COLO.
LINCOLN
KAN.
ARIZ.
N. MEX.
OKLA.
TEX.
FLAGSTAFF
TEMPE
ALBUQUERQUE
TUCSON